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Kuntz et al.

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(54) **SOUND REDUCTION DEVICE FOR
ROCKING PISTON PUMPS AND
COMPRESSORS**

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F04B 39/00 (2006.01)
F04B 53/00 (2006.01)
F04B 39/12 (2006.01)

(52) **U.S. Cl.**
CPC **F04B 39/0027** (2013.01); **F04B 39/0061** (2013.01); **F04B 39/12** (2013.01); **F04B 53/001** (2013.01)

(58) **Field of Classification Search**
CPC Y10S 181/403; F04B 39/0061; F04B 39/0027; F04B 39/005; F04B 39/12; F04B 53/001

See application file for complete search history.

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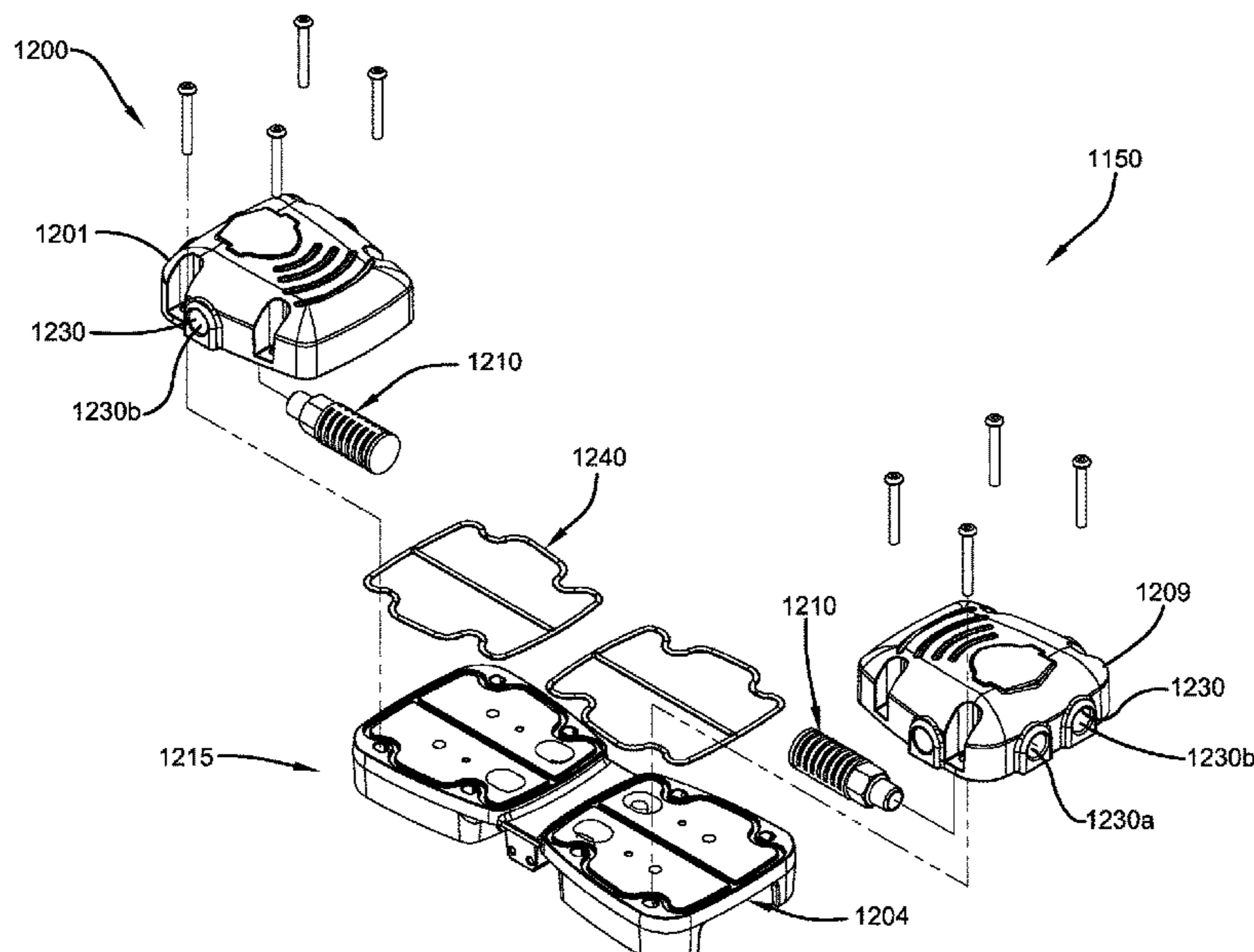
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(57) **ABSTRACT**

A rocking piston vacuum pump or compressor may have a sound attenuation assembly. The sound attenuation assembly may comprise a sound attenuation chamber. The chamber may have a first silencer disposed therein with sound dampening foam disposed therein. A second silencer may be disposed in series relative to the first silencer and may be disposed externally of the sound attenuation chamber.

15 Claims, 22 Drawing Sheets



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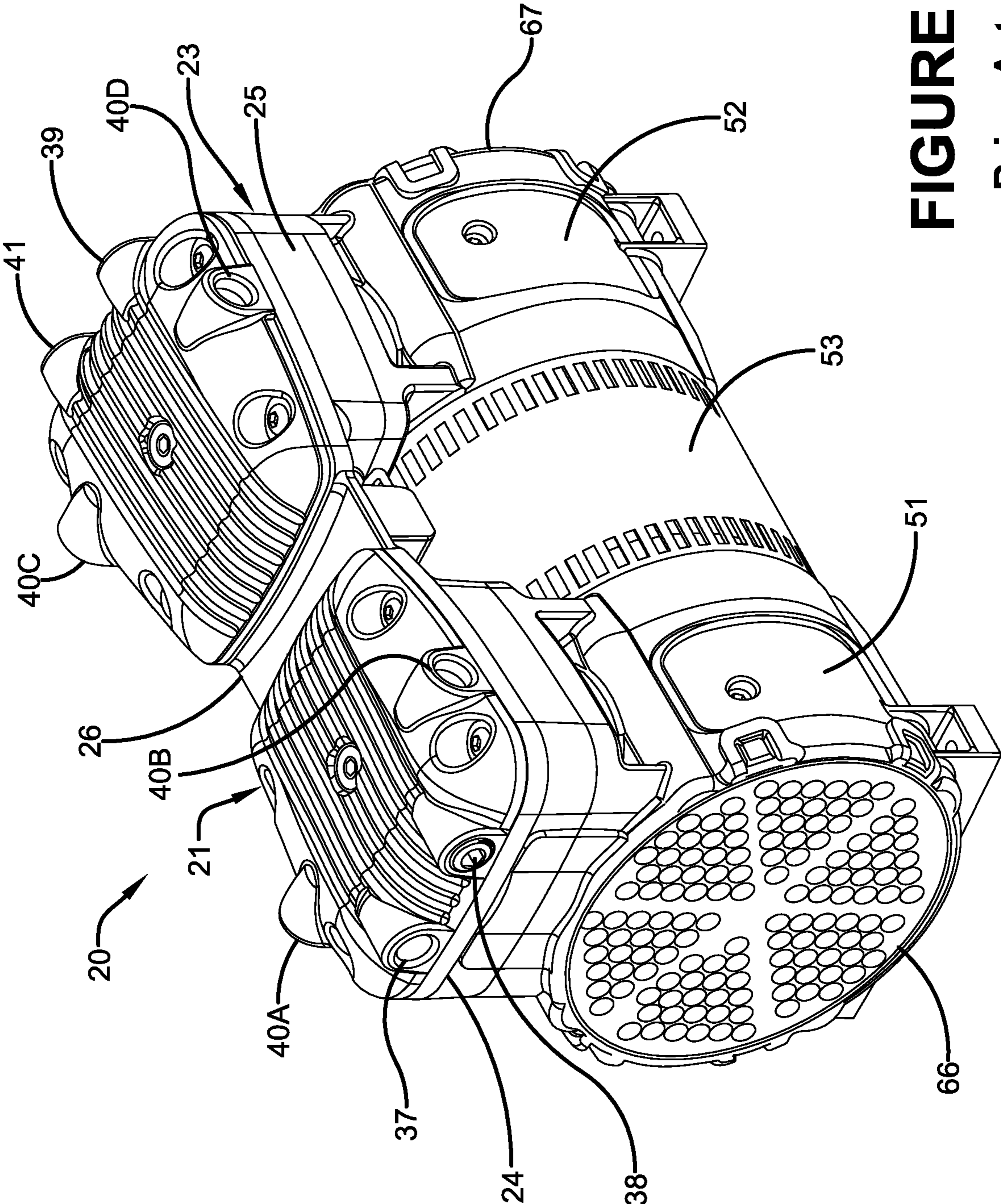


FIGURE 1
Prior Art

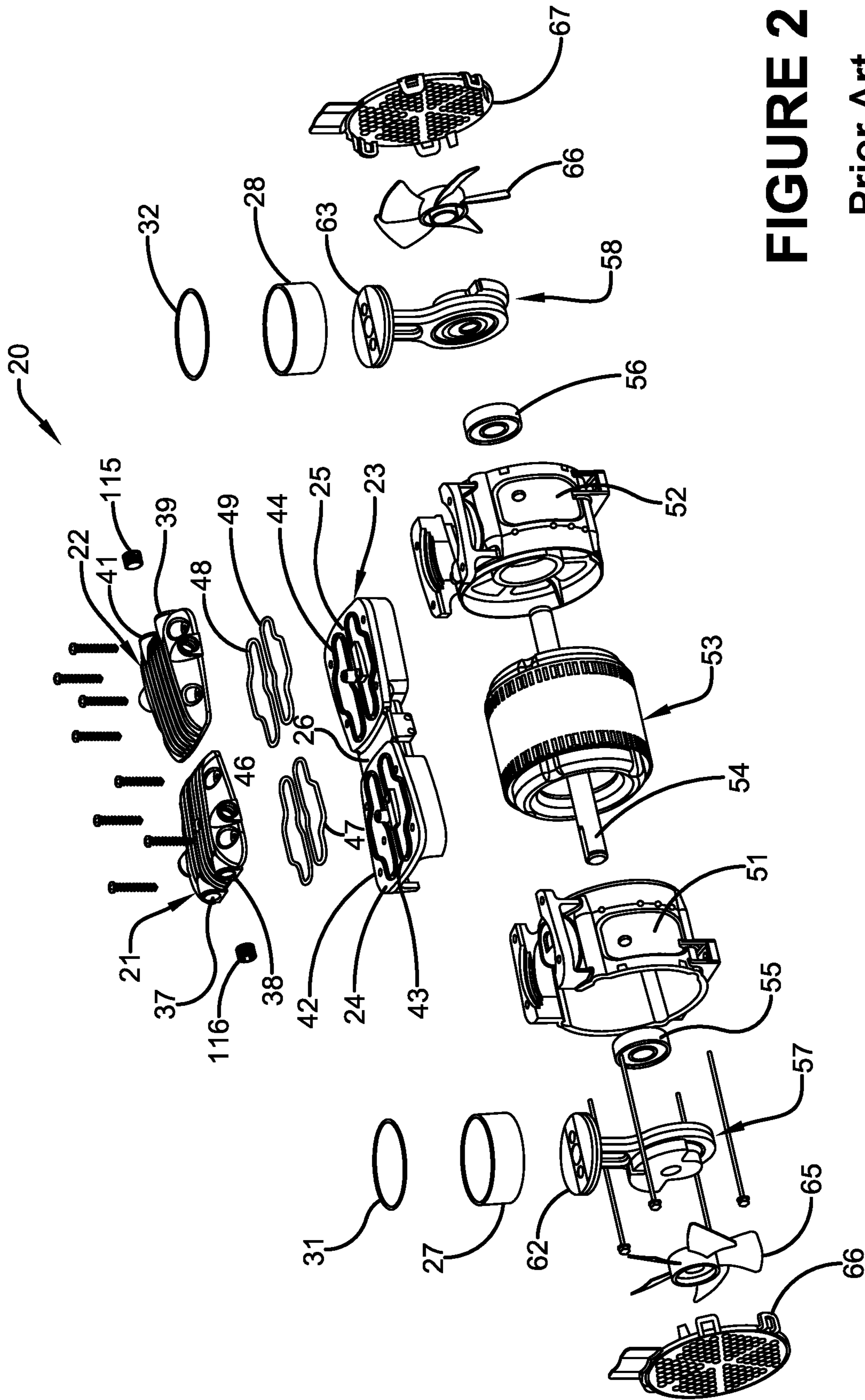


FIGURE 2

Prior Art

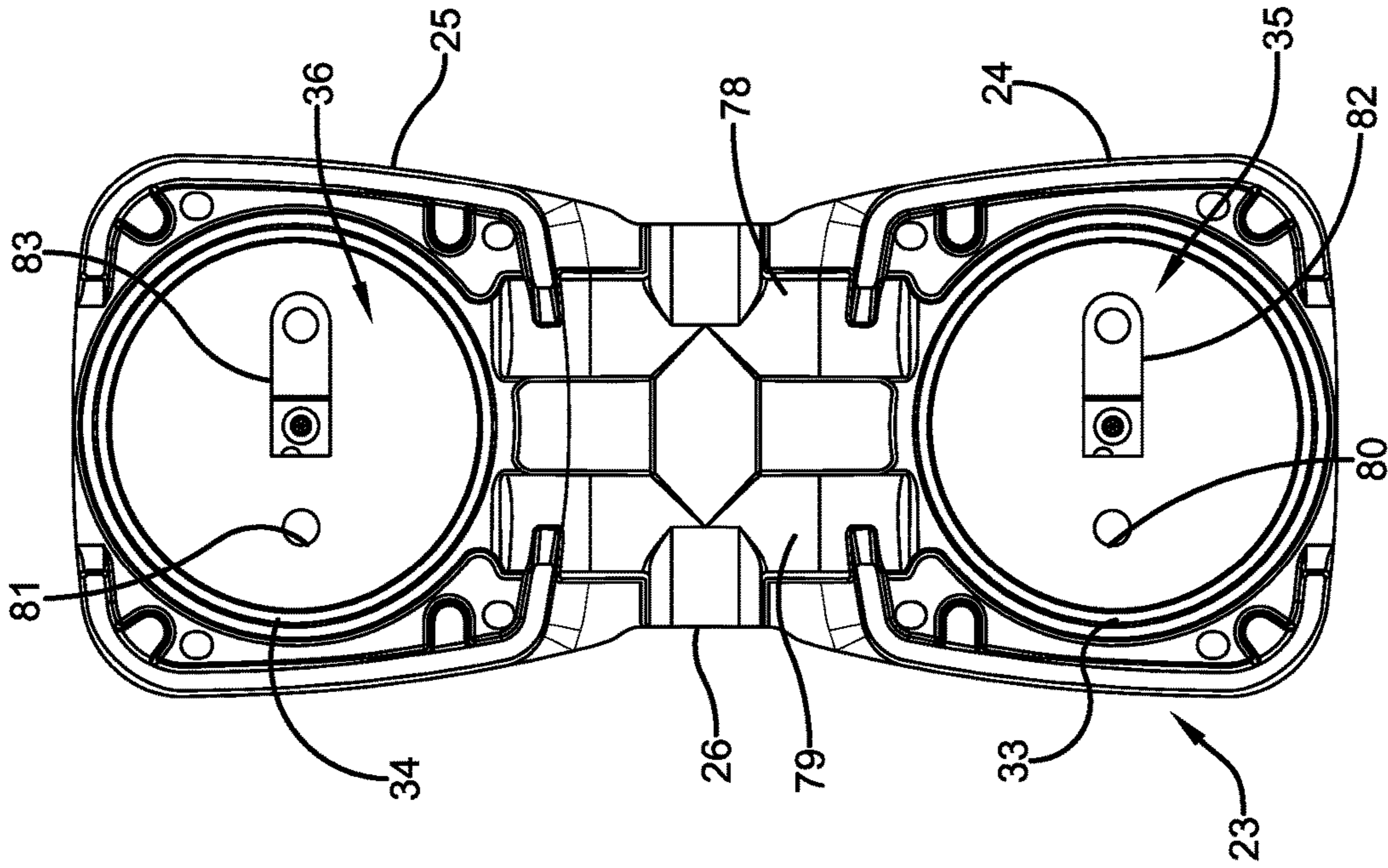


FIGURE 3B

Prior Art

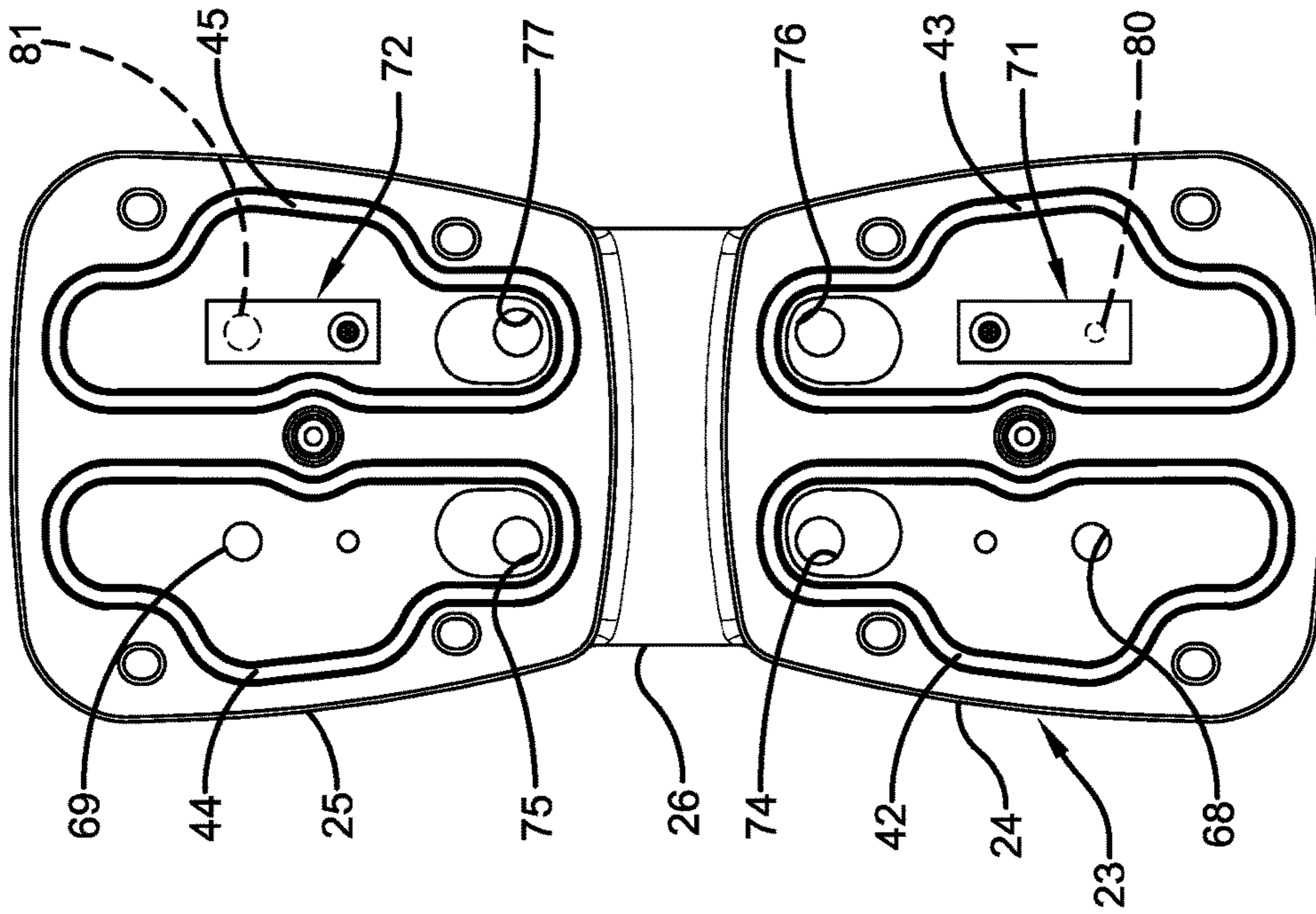


FIGURE 3A

Prior Art

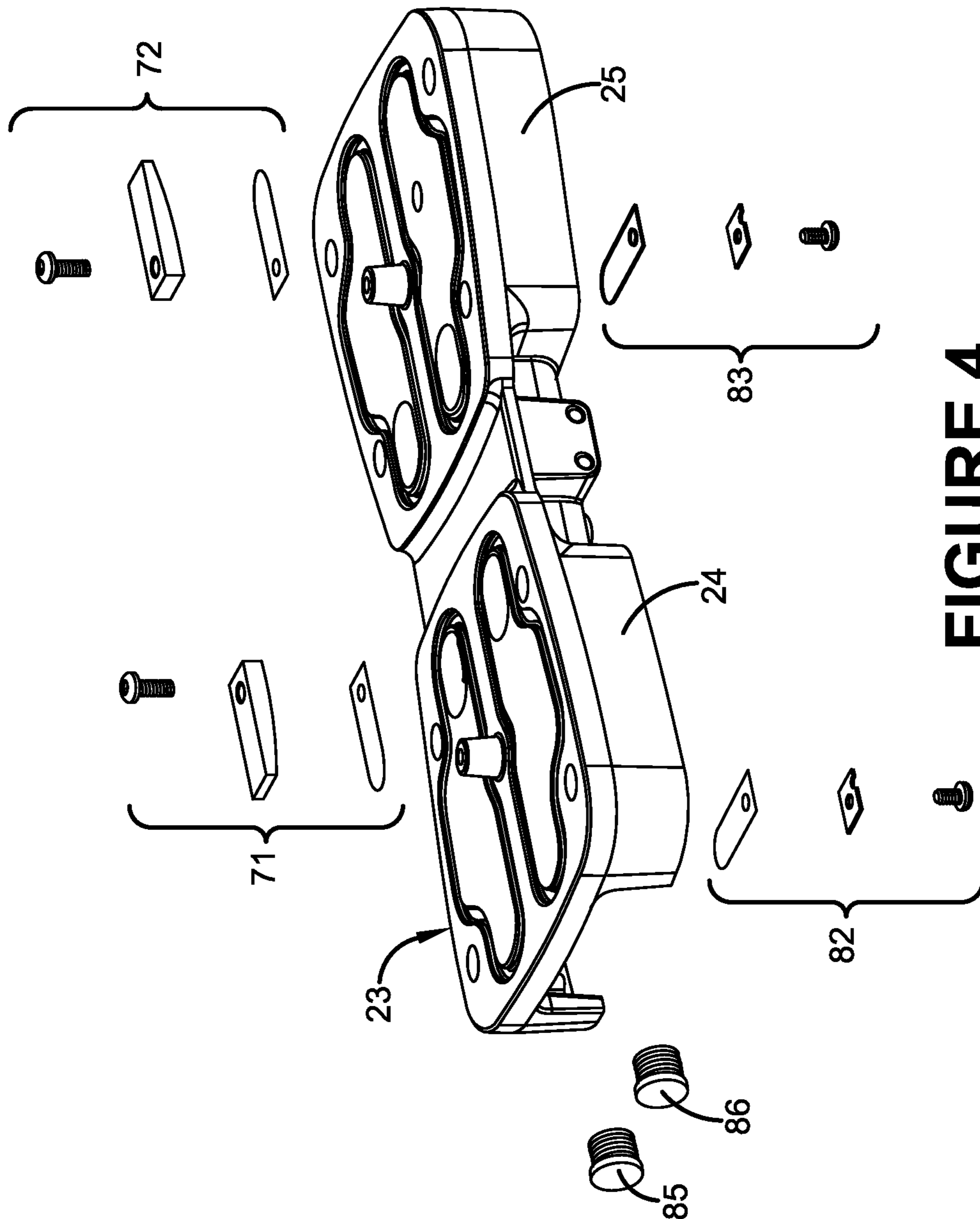


FIGURE 4

Prior Art

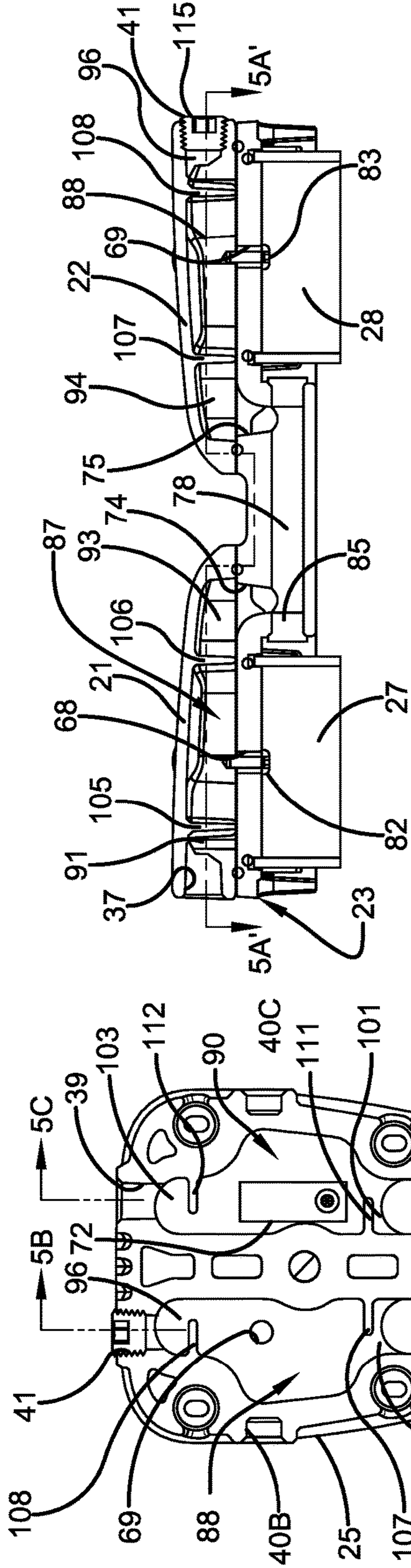


FIGURE 5A

Prior Art

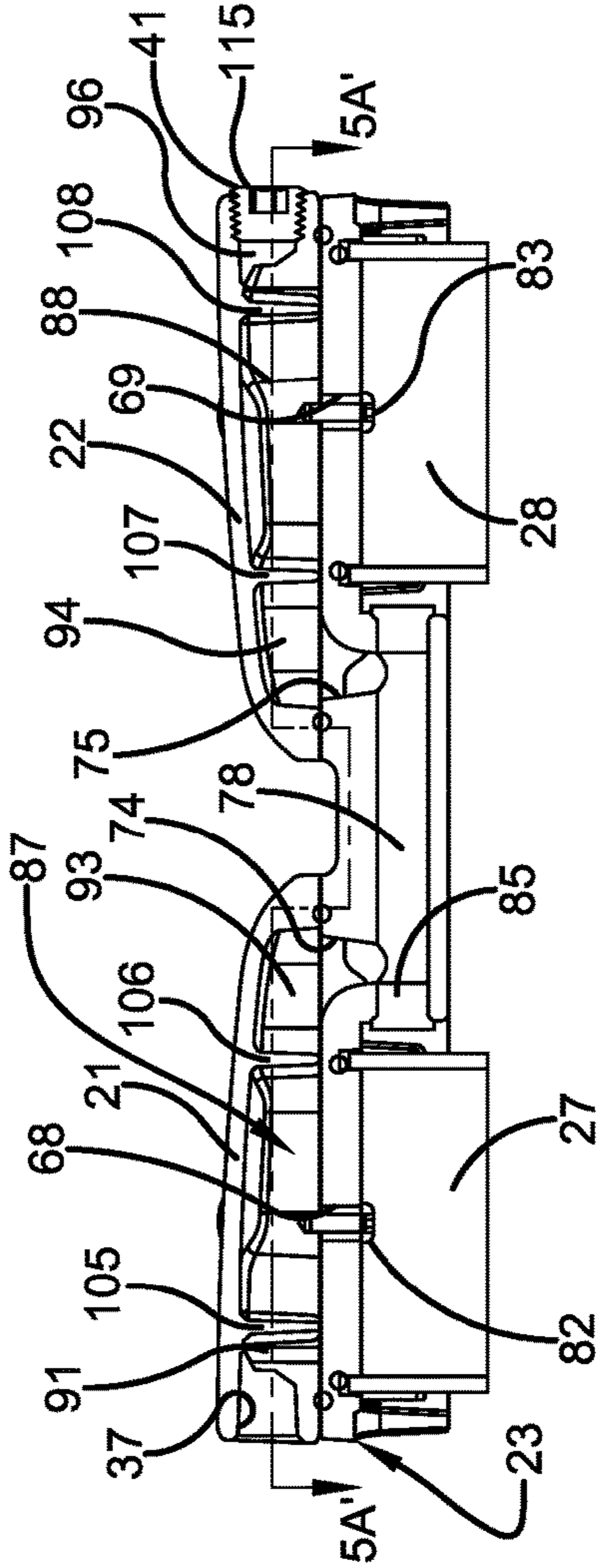


FIGURE 5B

Prior Art

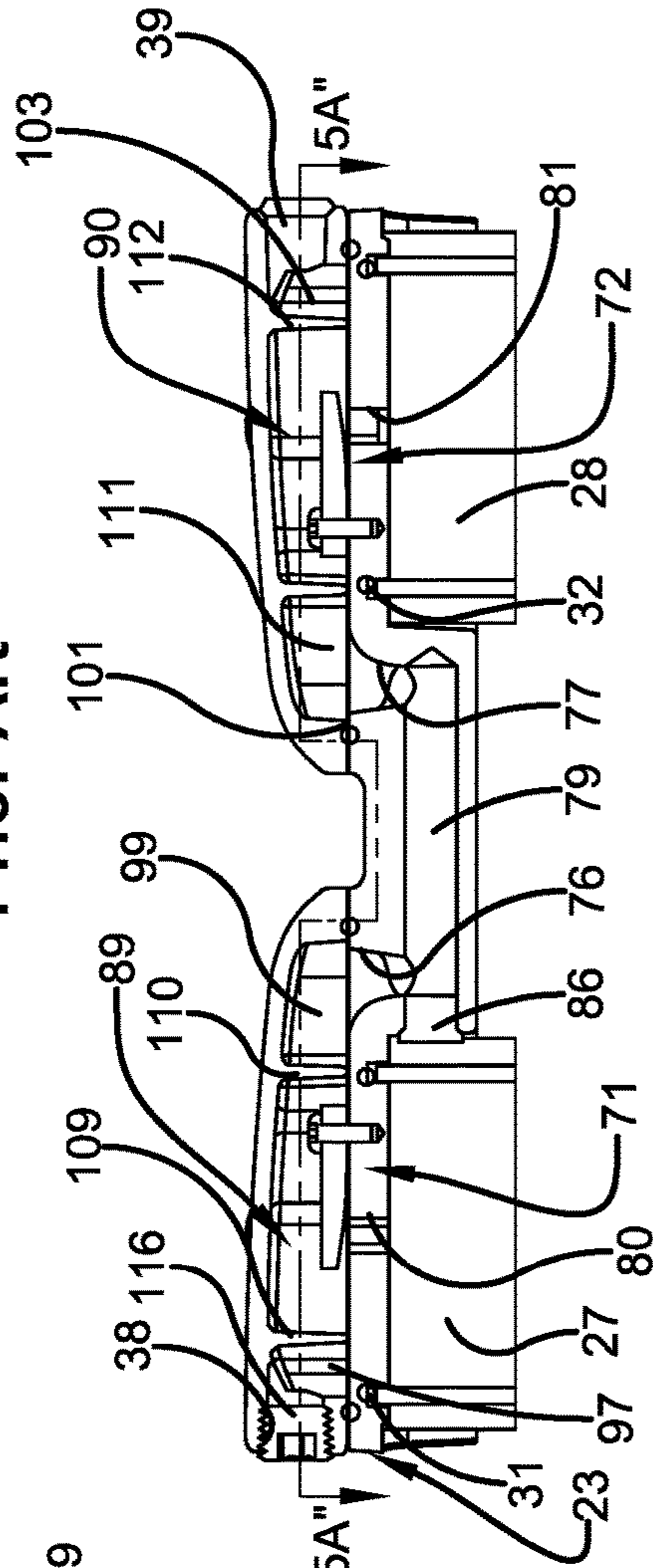


FIGURE 5C

Prior Art

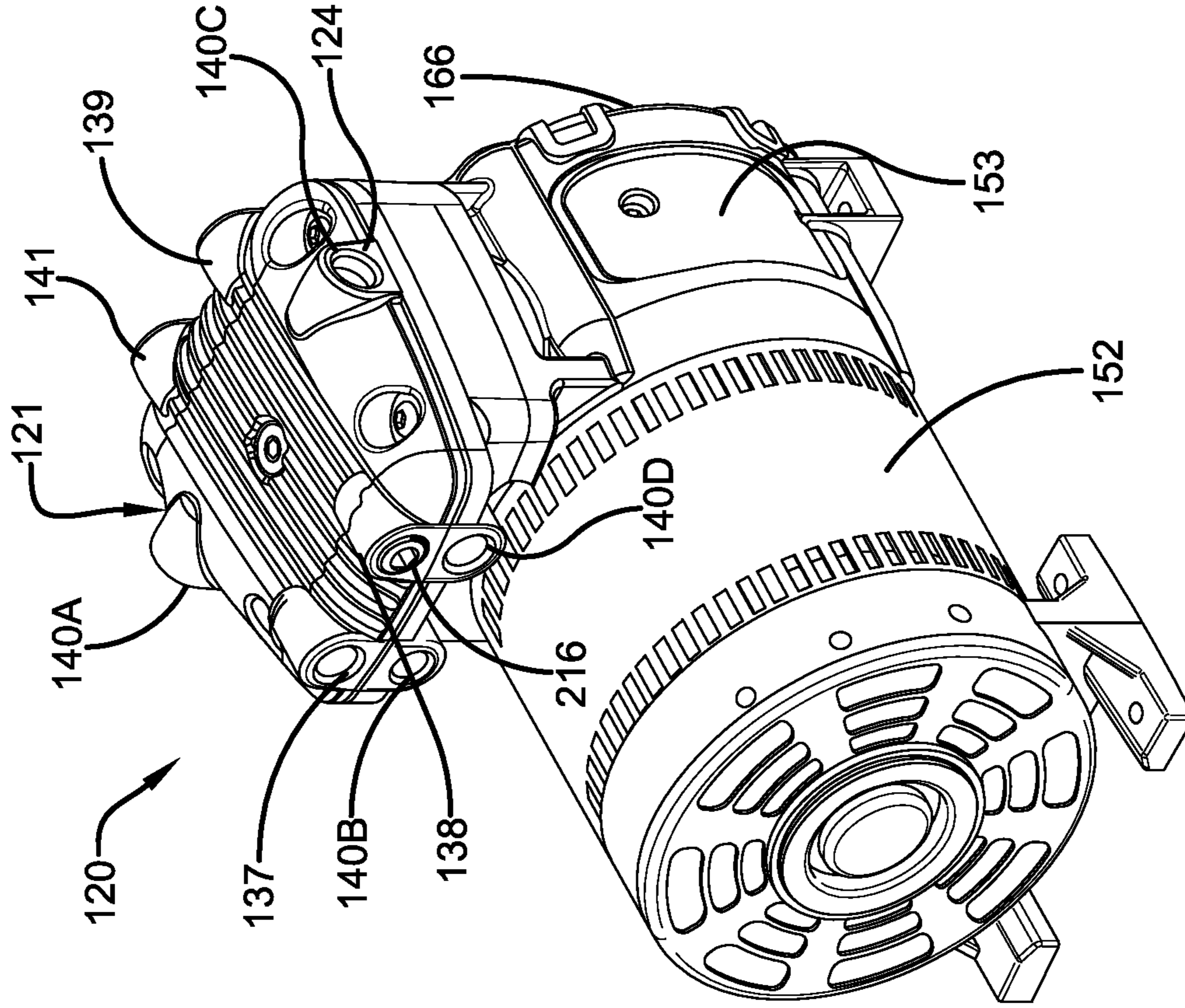


FIGURE 6B
Prior Art

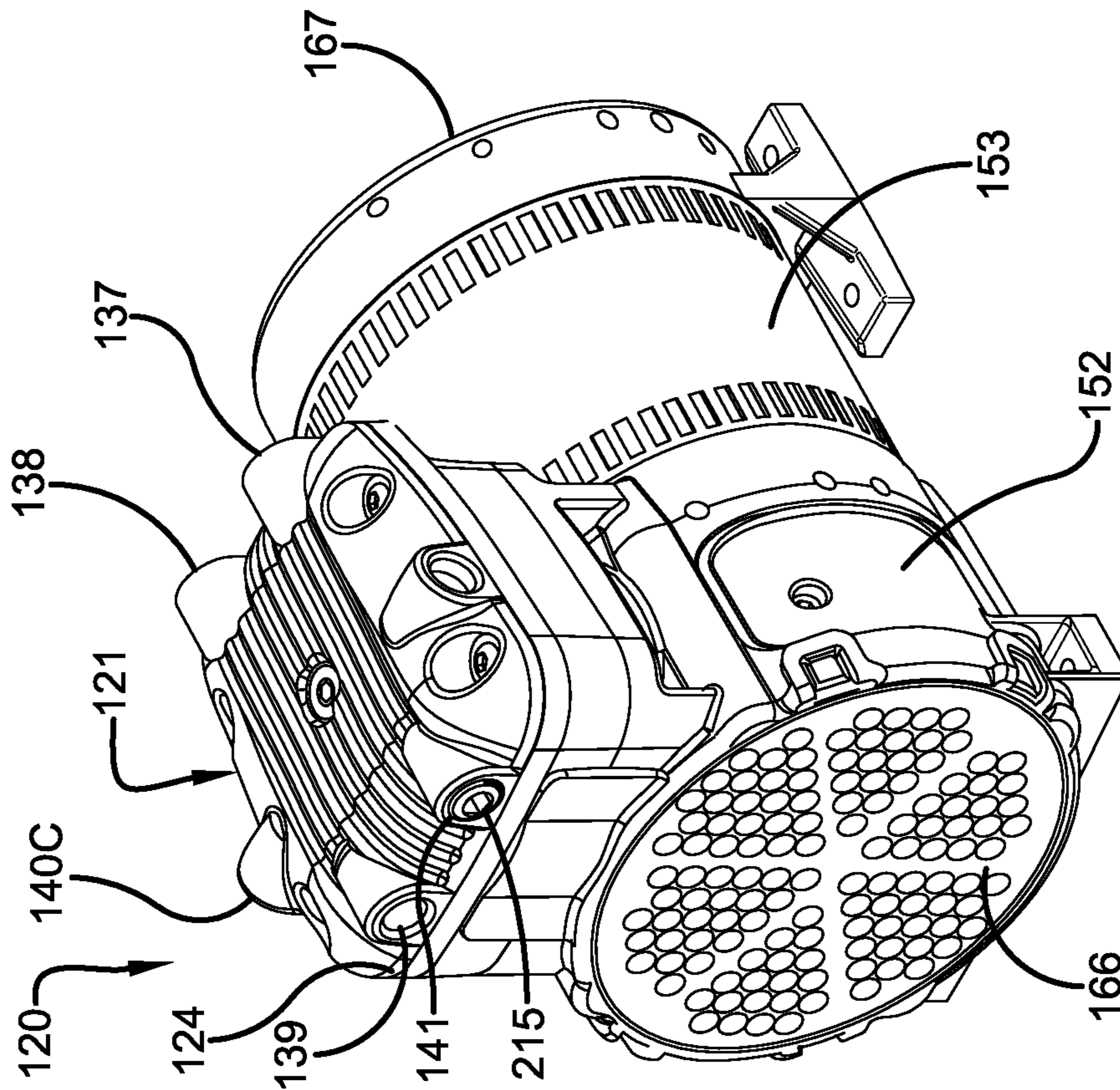


FIGURE 6A
Prior Art

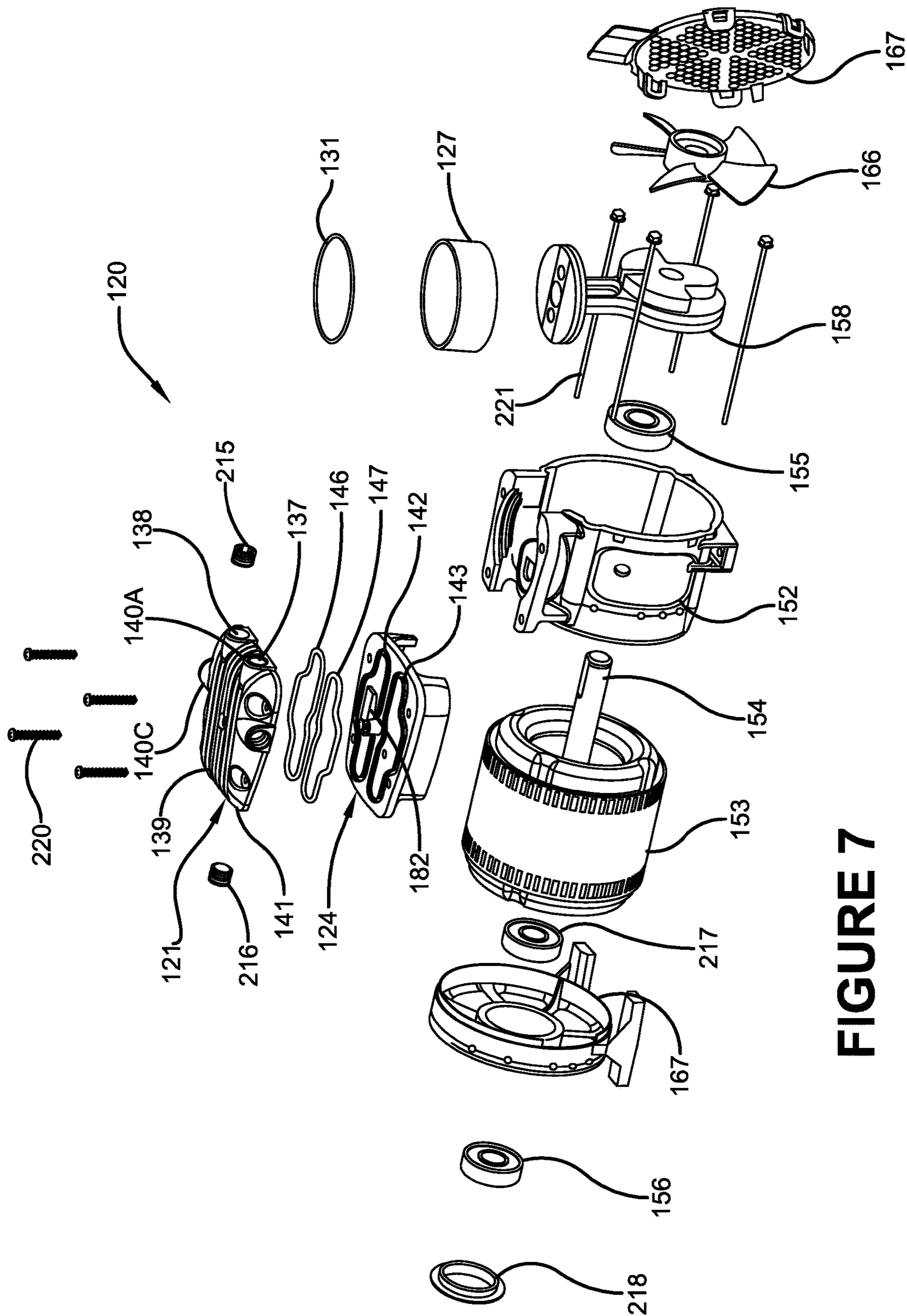


FIGURE 7

Prior Art

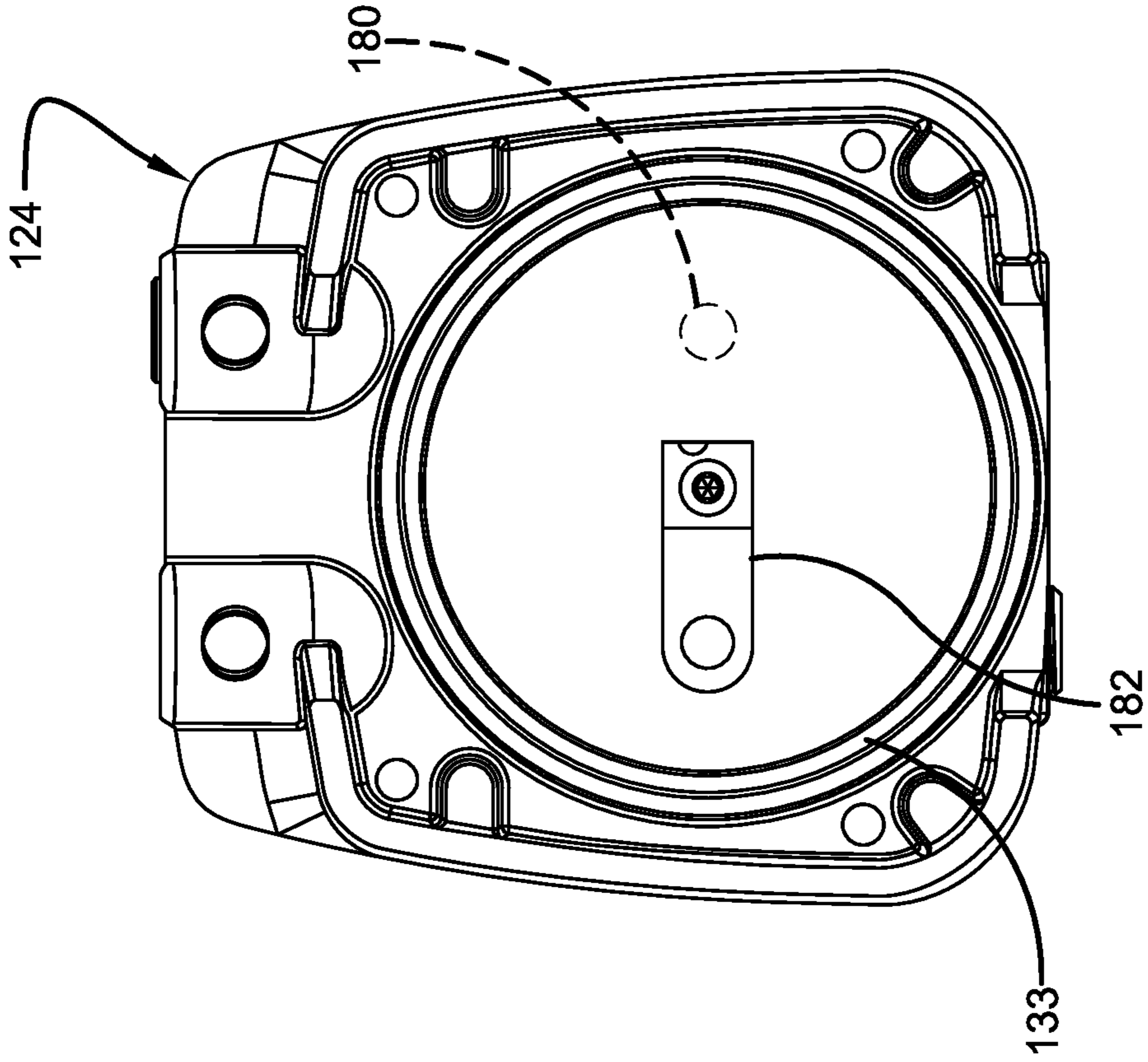


FIGURE 8B

Prior Art

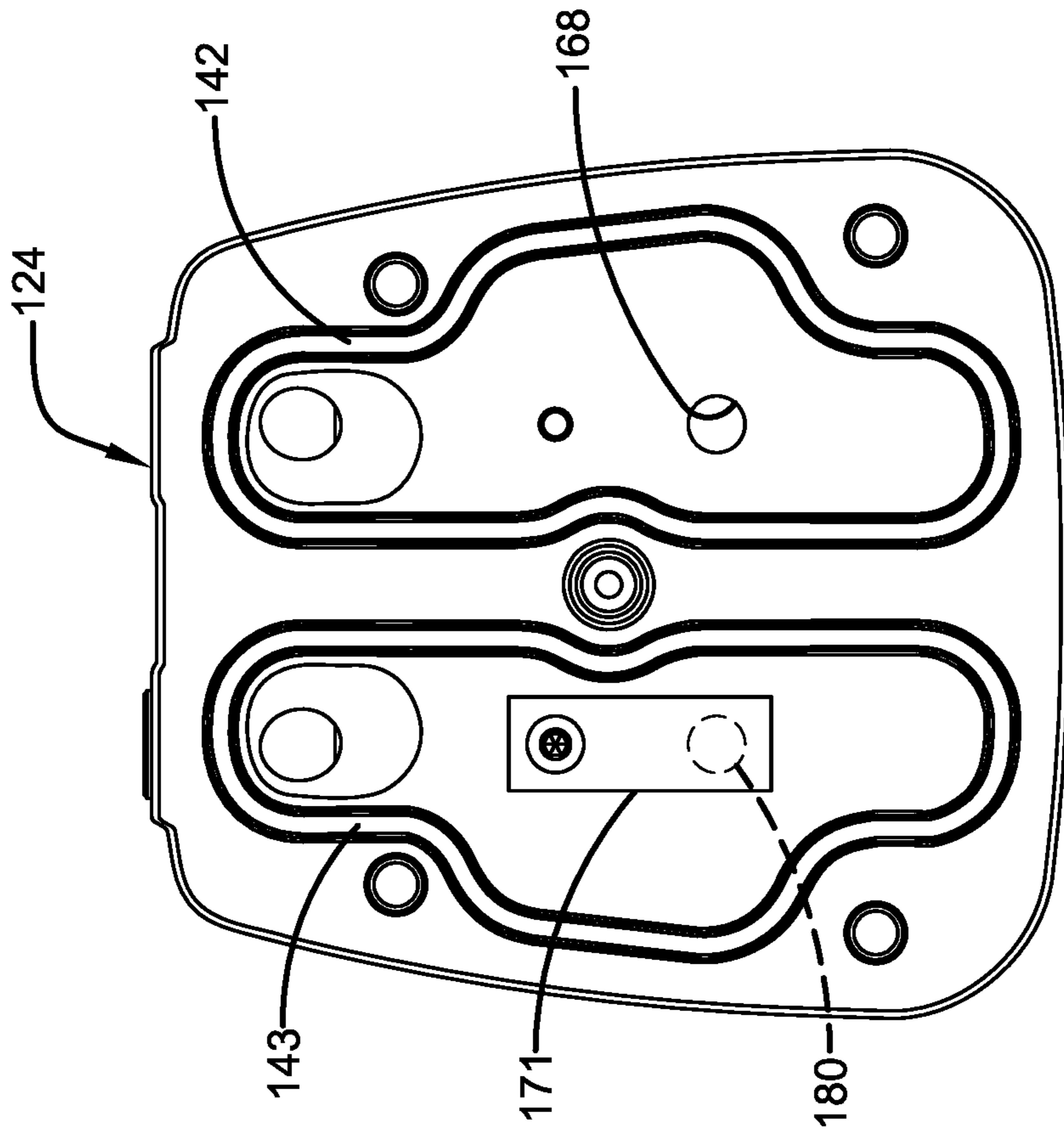


FIGURE 8A

Prior Art

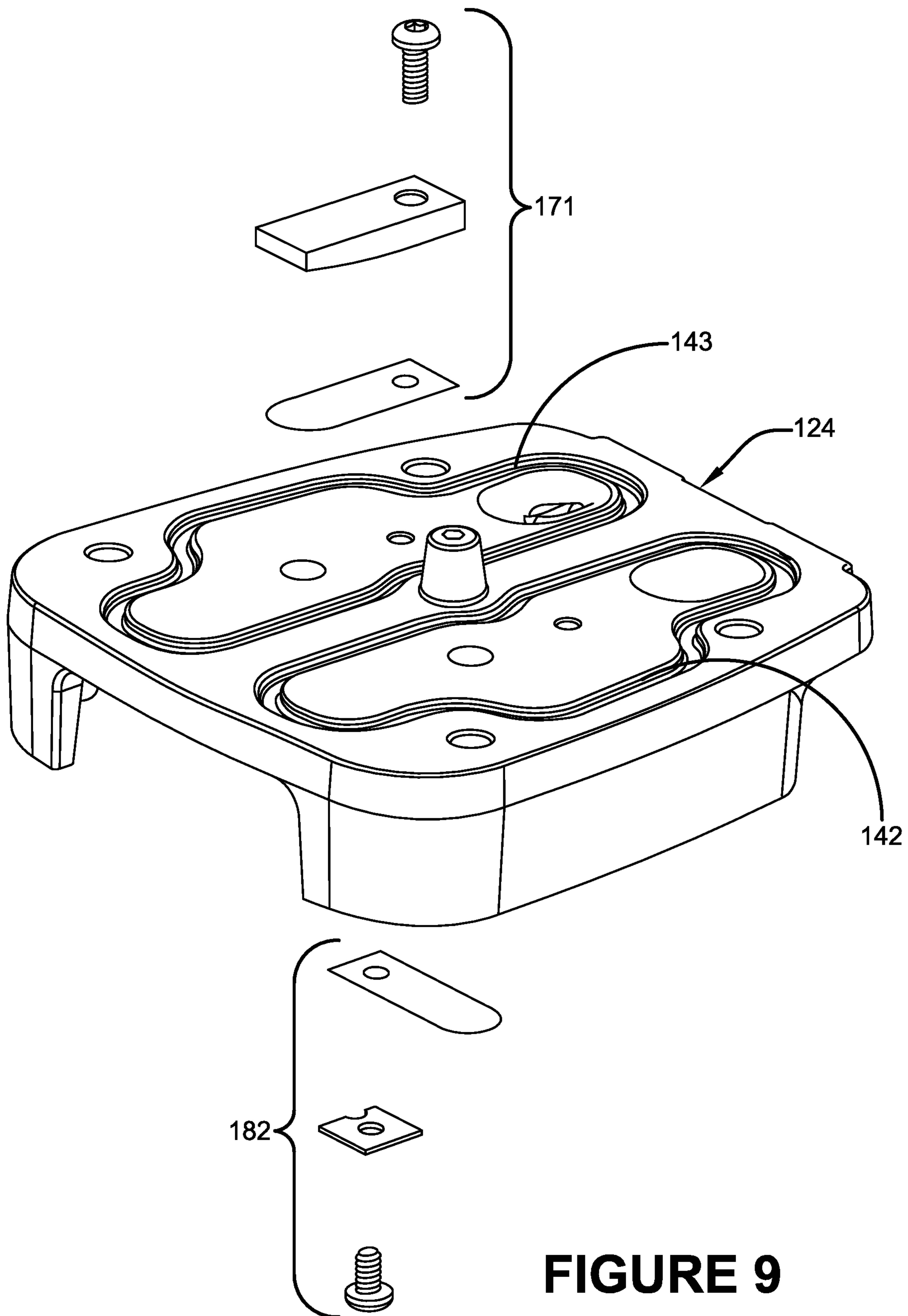


FIGURE 9

Prior Art

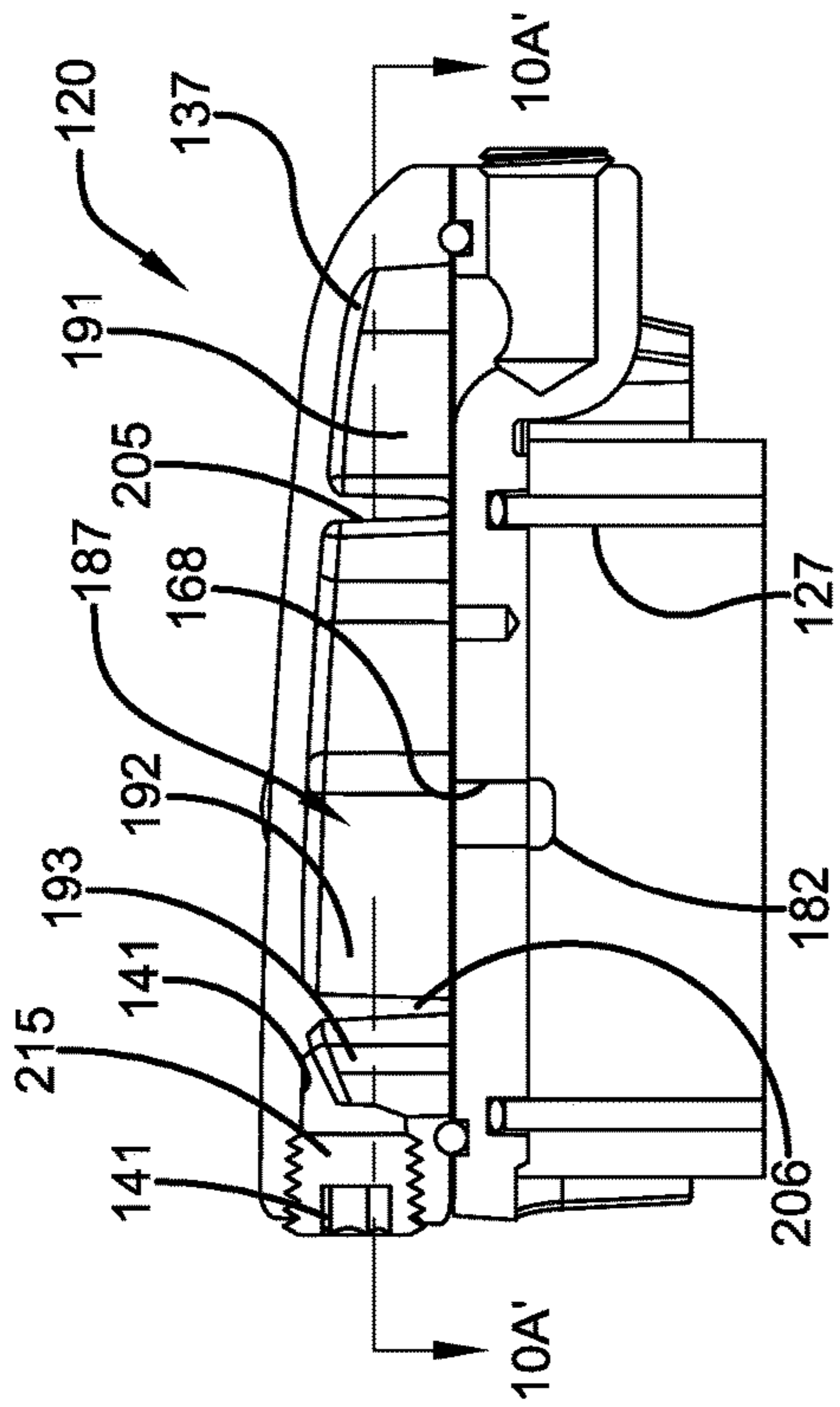


FIGURE 10B

Prior Art

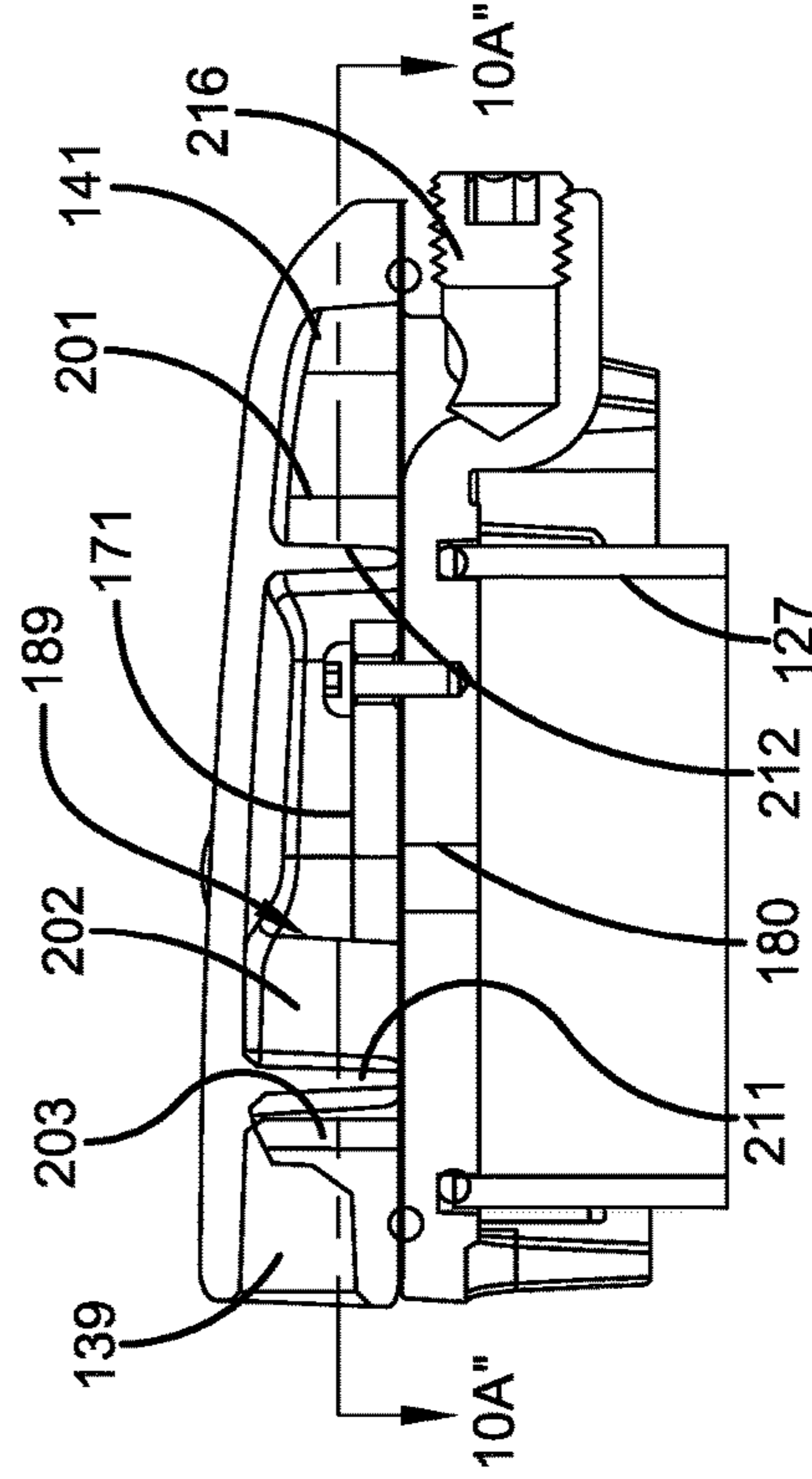


FIGURE 10C

Prior Art

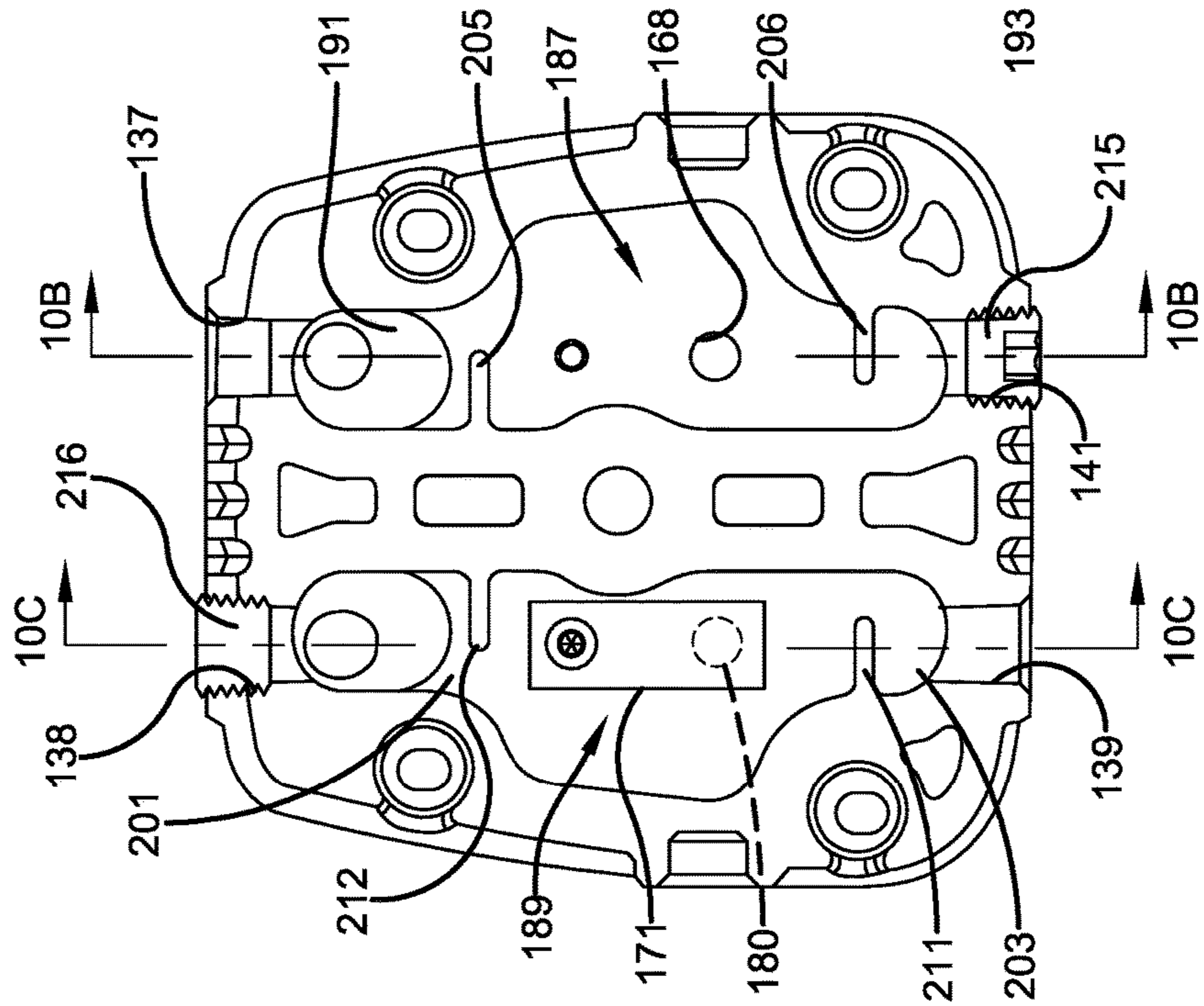


FIGURE 10A

Prior Art

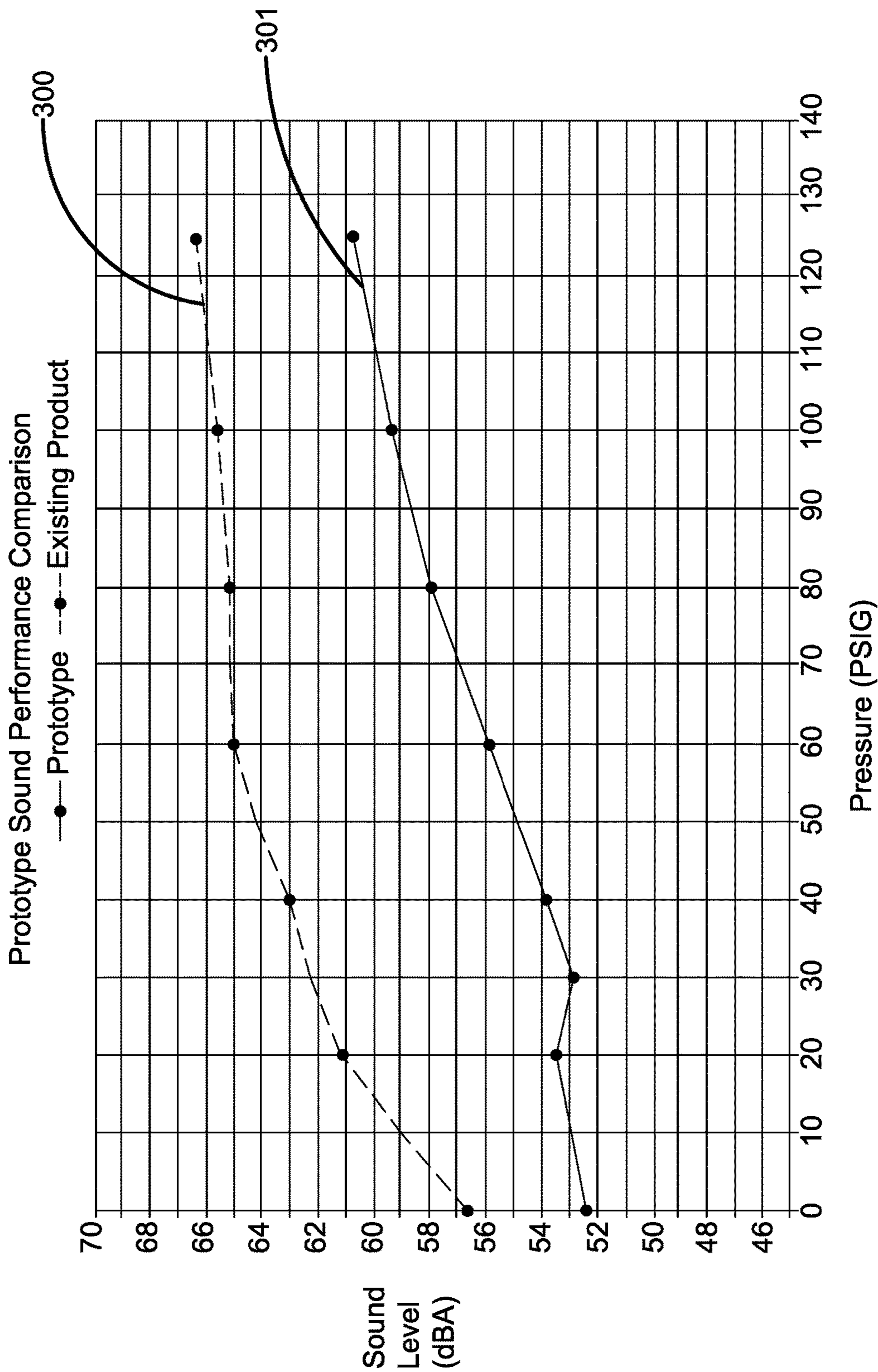


FIGURE 11

Prior Art

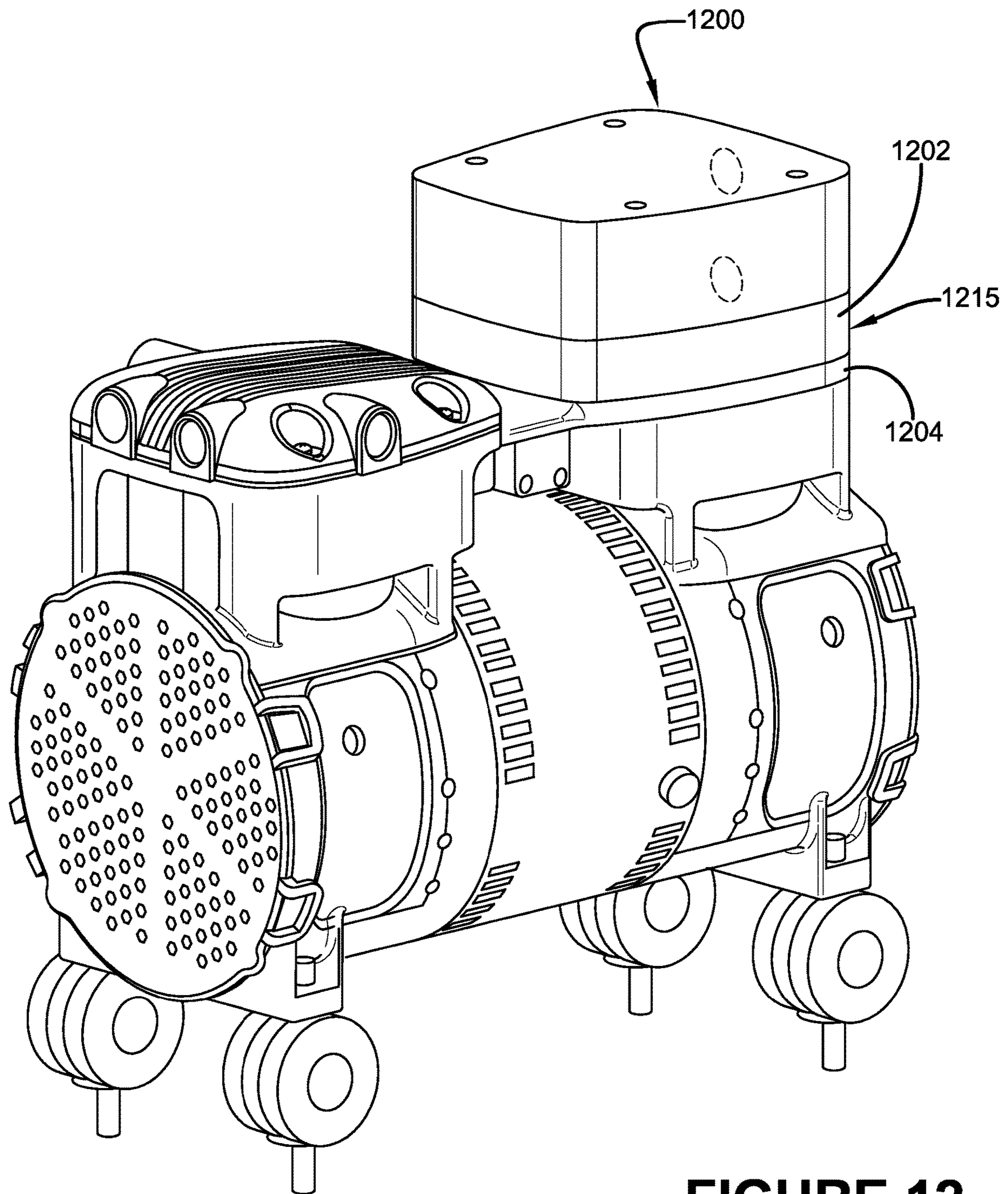


FIGURE 12

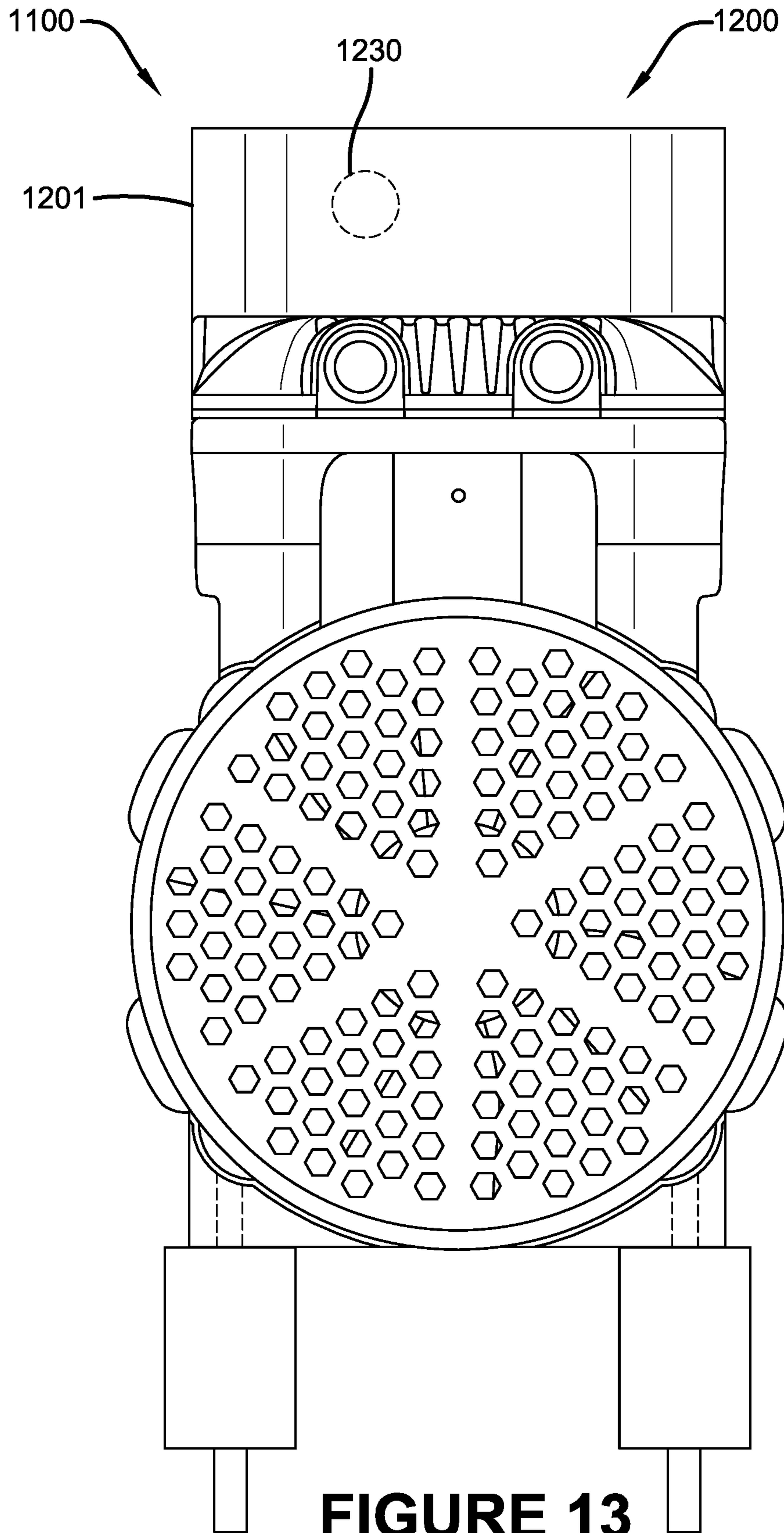


FIGURE 13

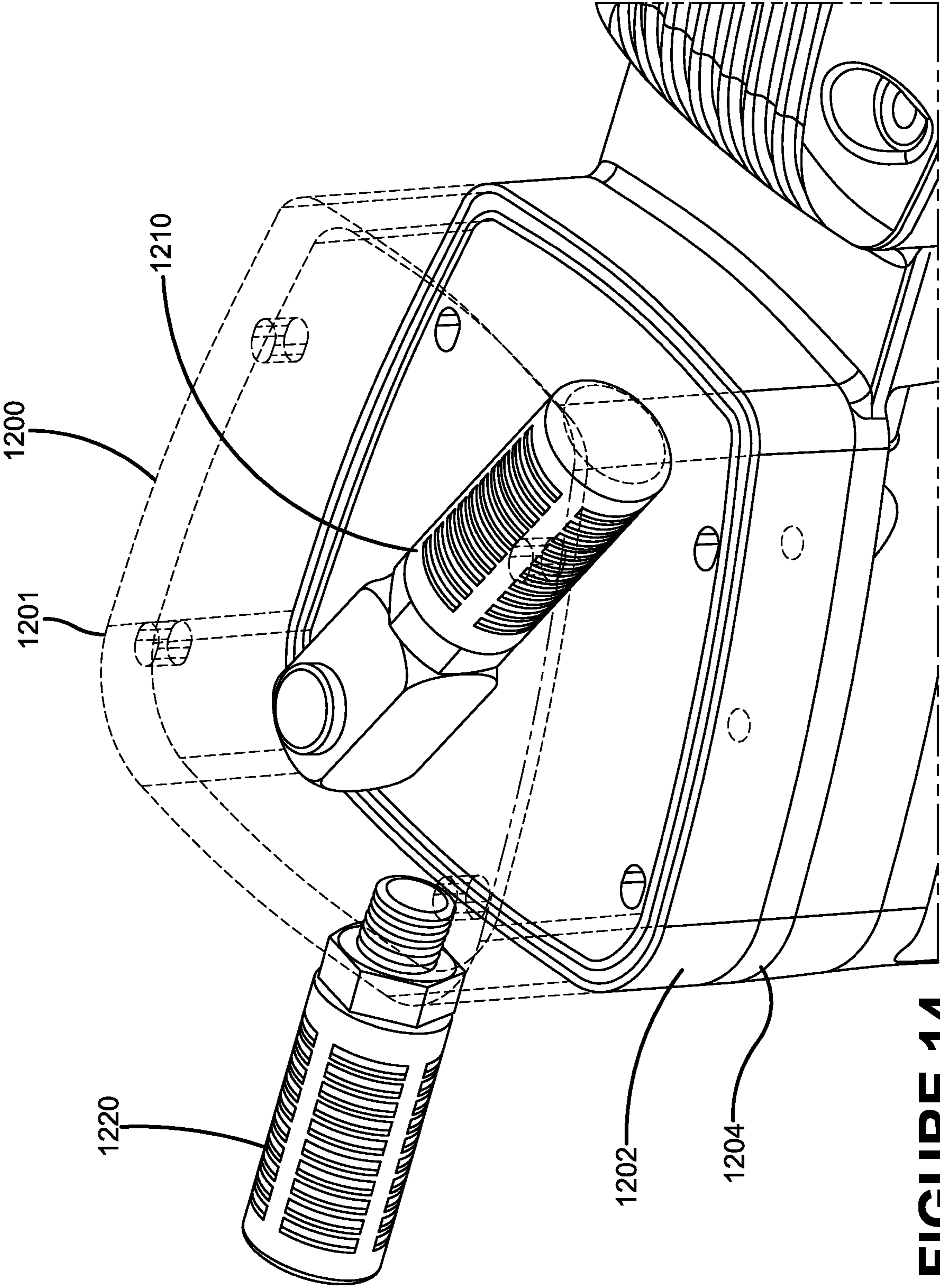


FIGURE 14

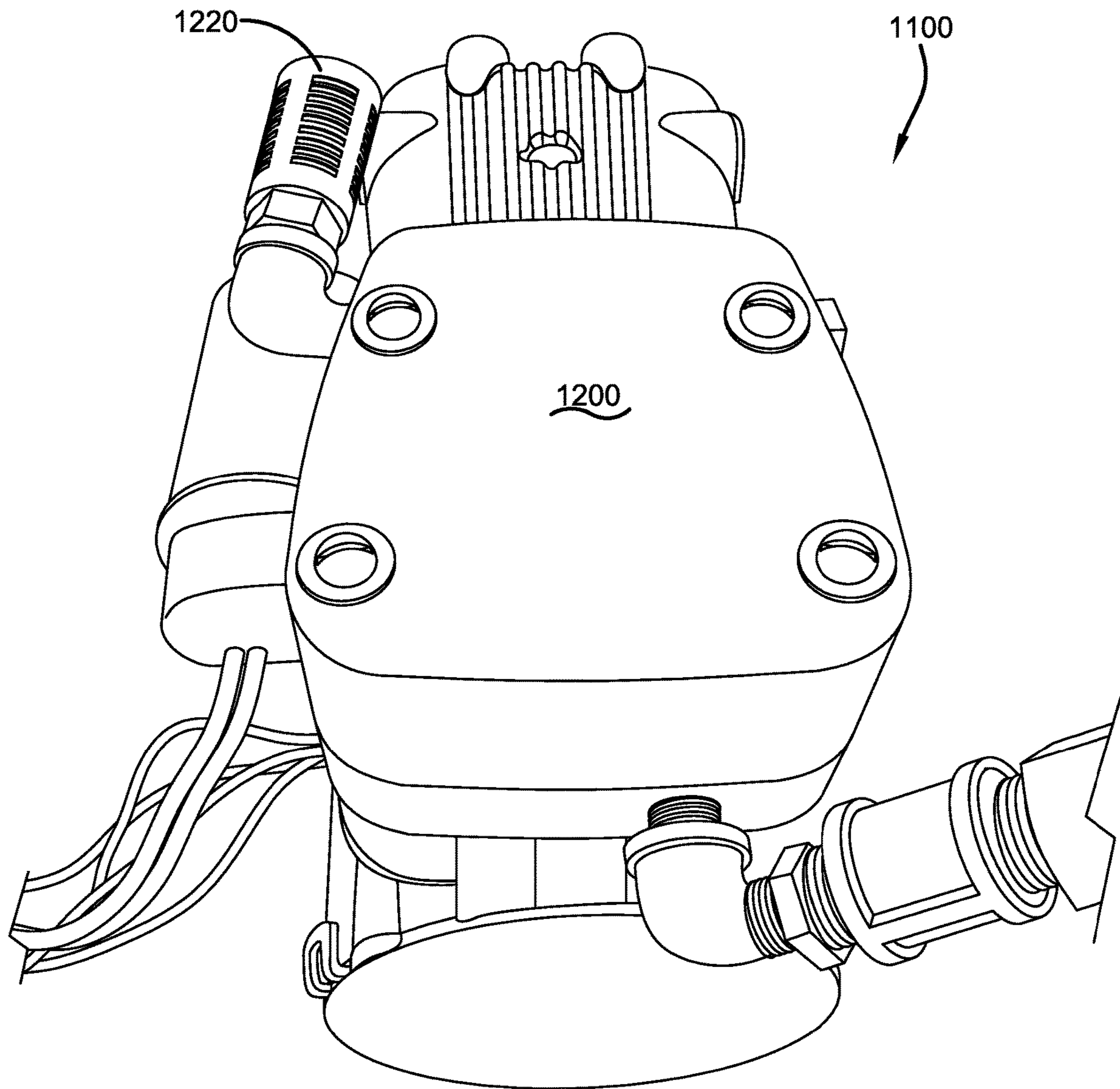


FIGURE 15A

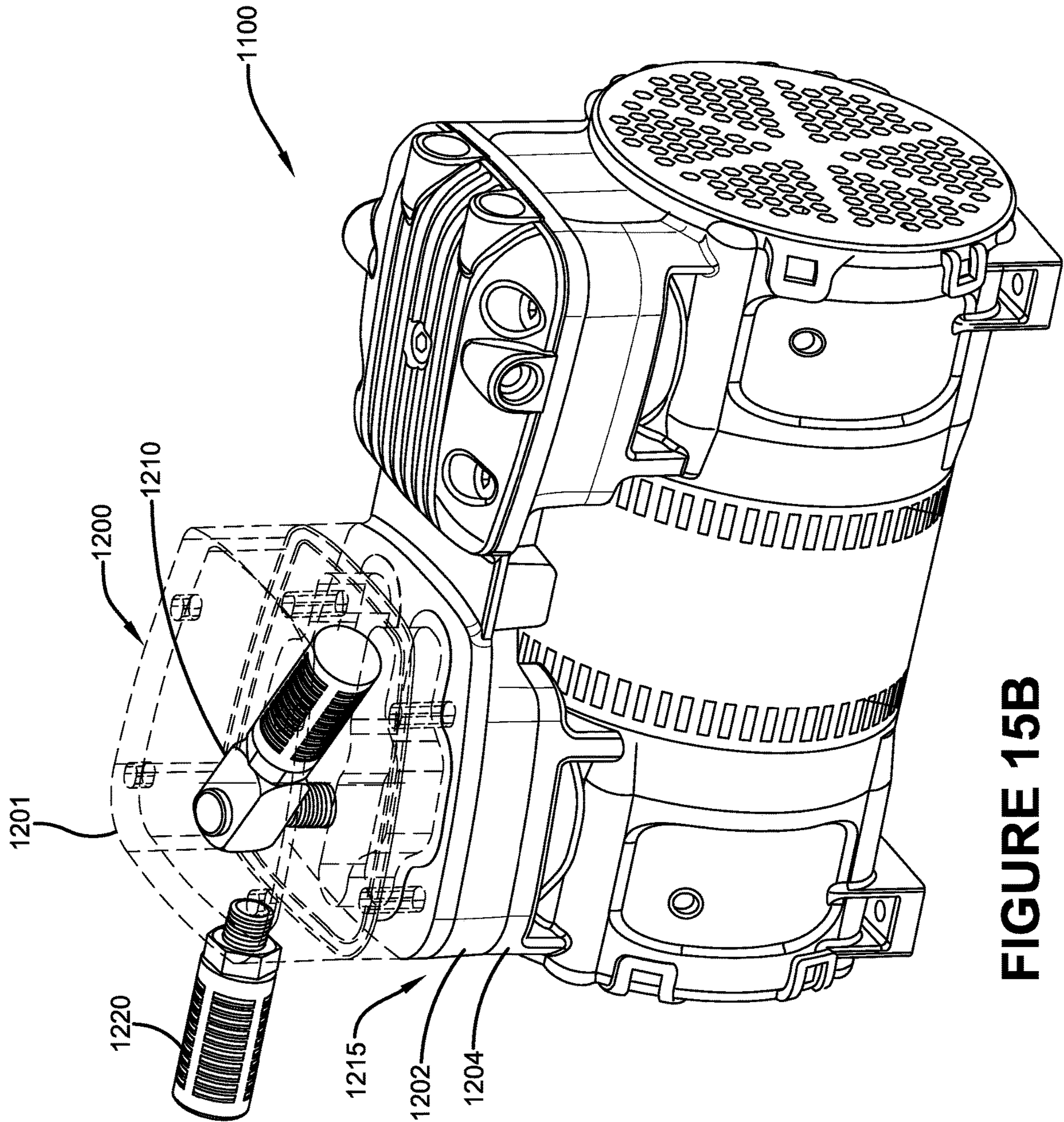


FIGURE 15B

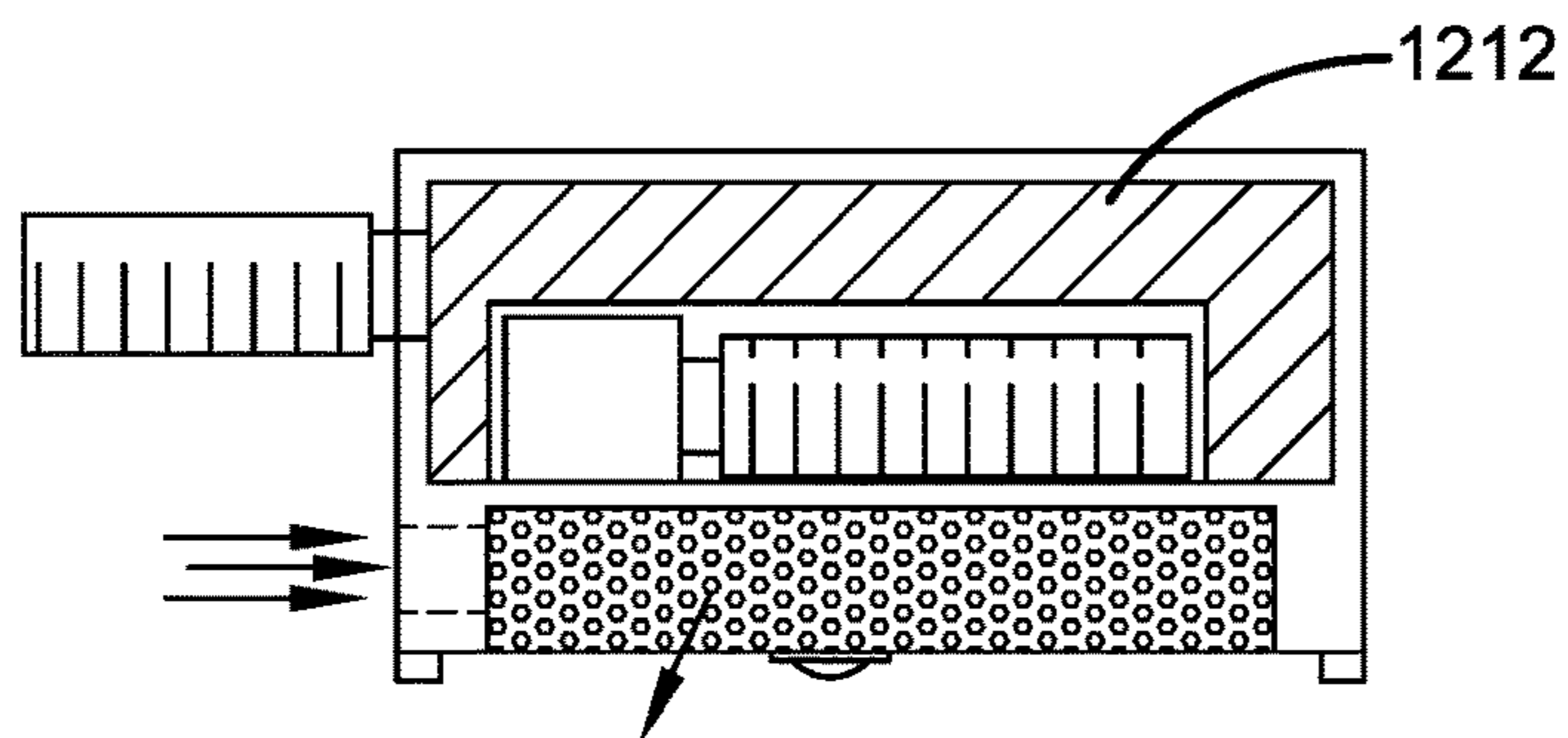


FIGURE 16B

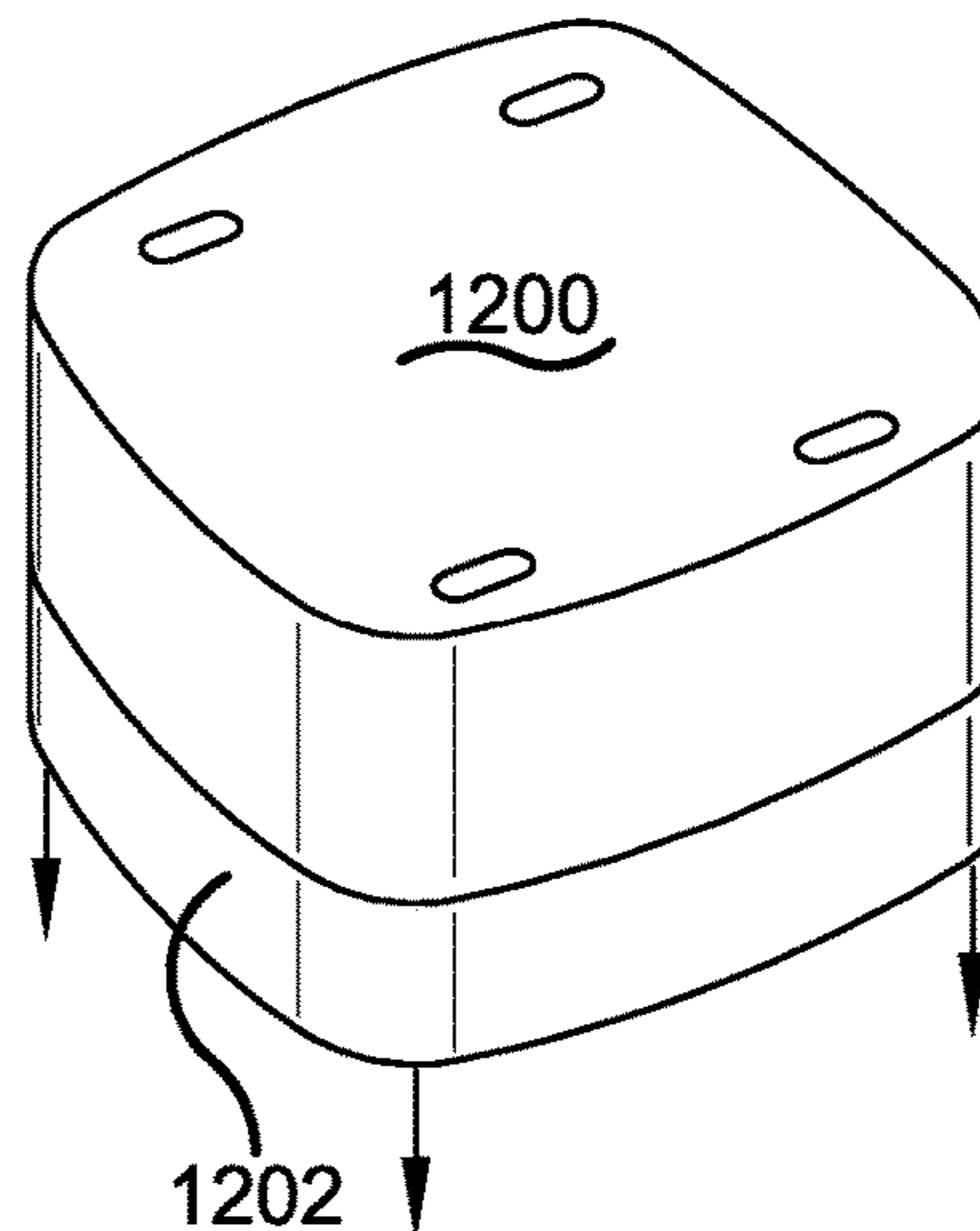


FIGURE 16A

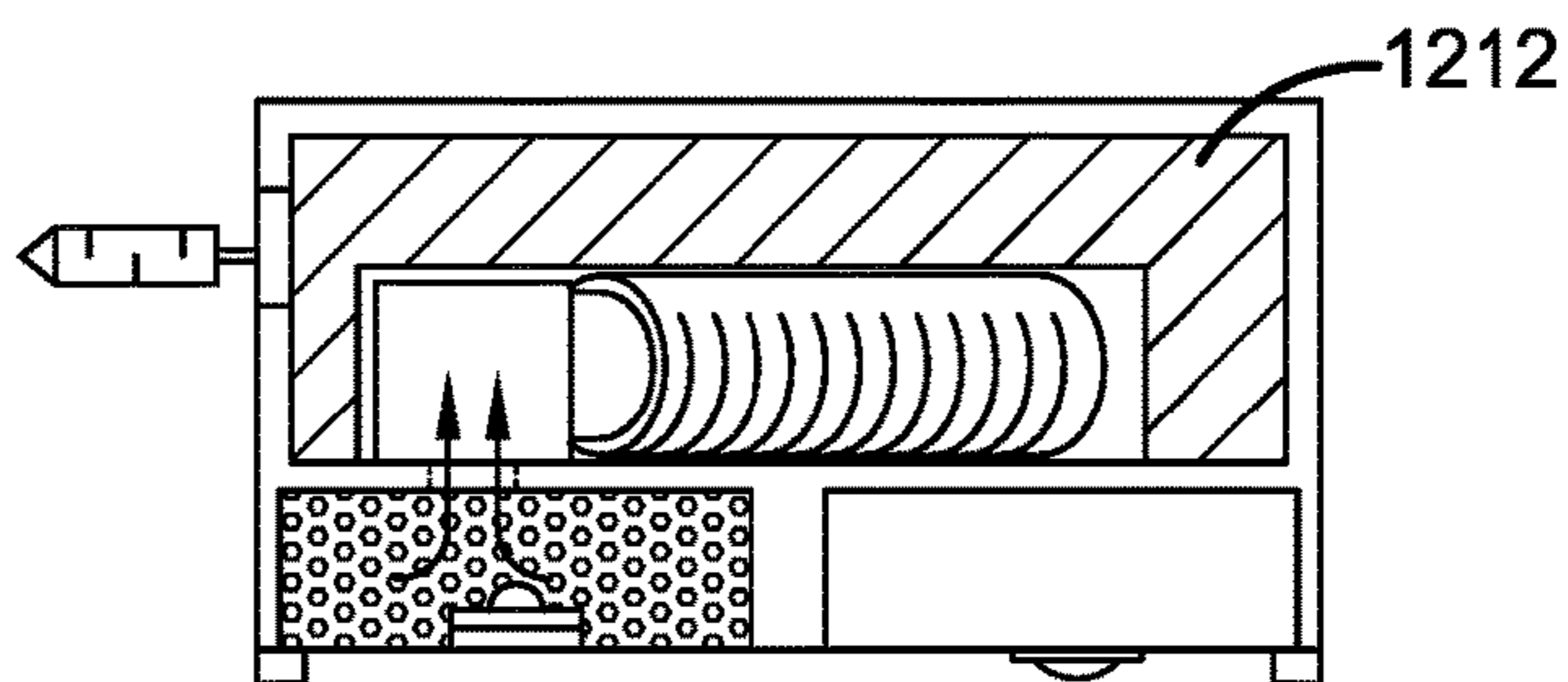


FIGURE 16C

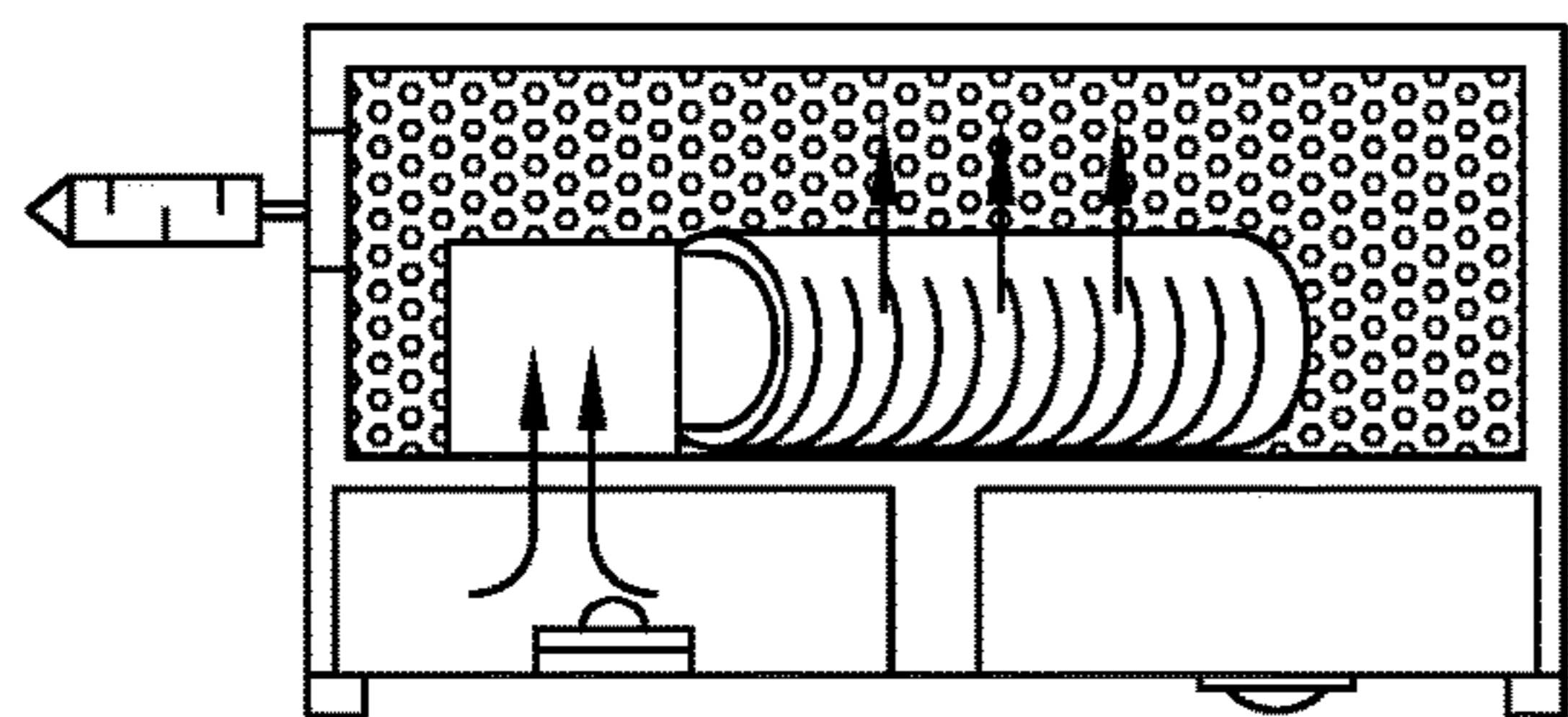


FIGURE 16D

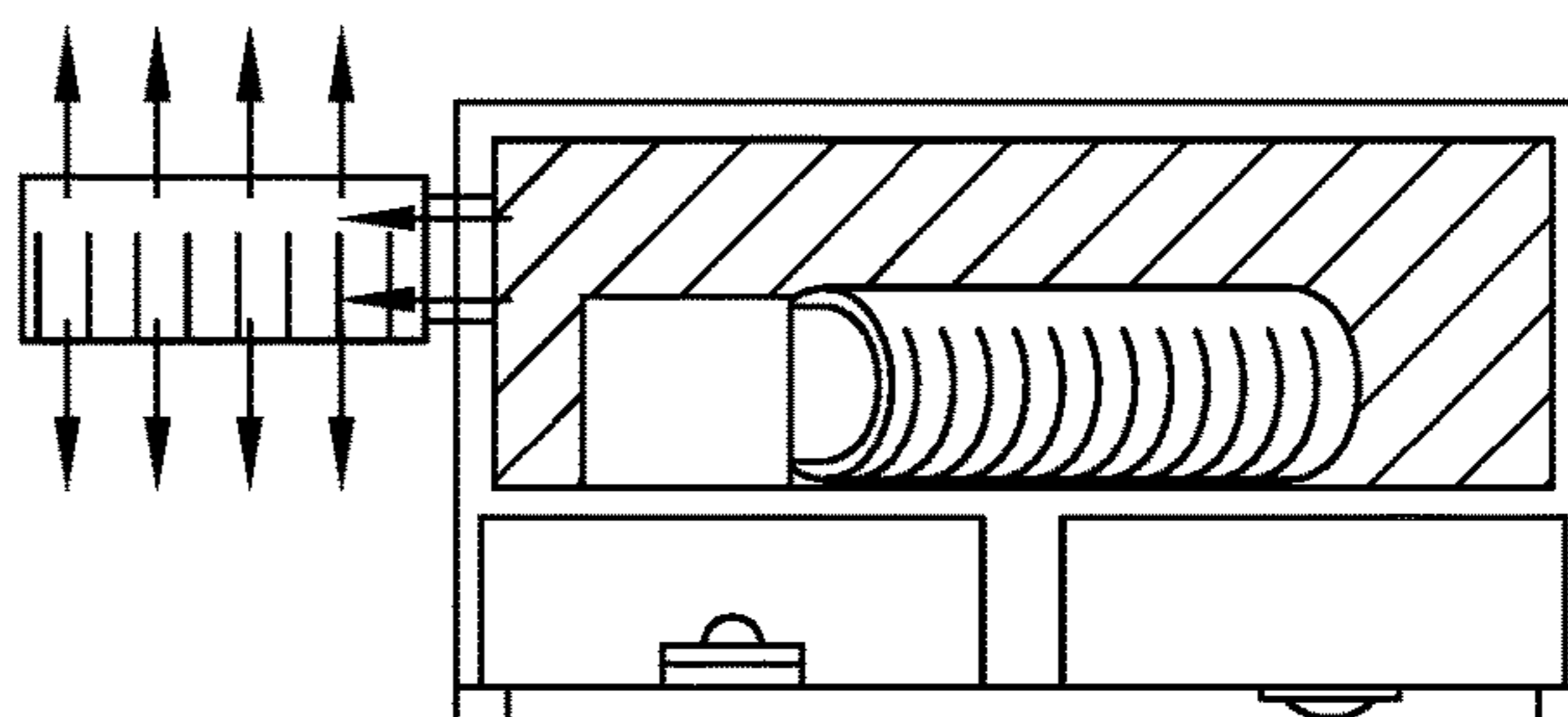


FIGURE 16E

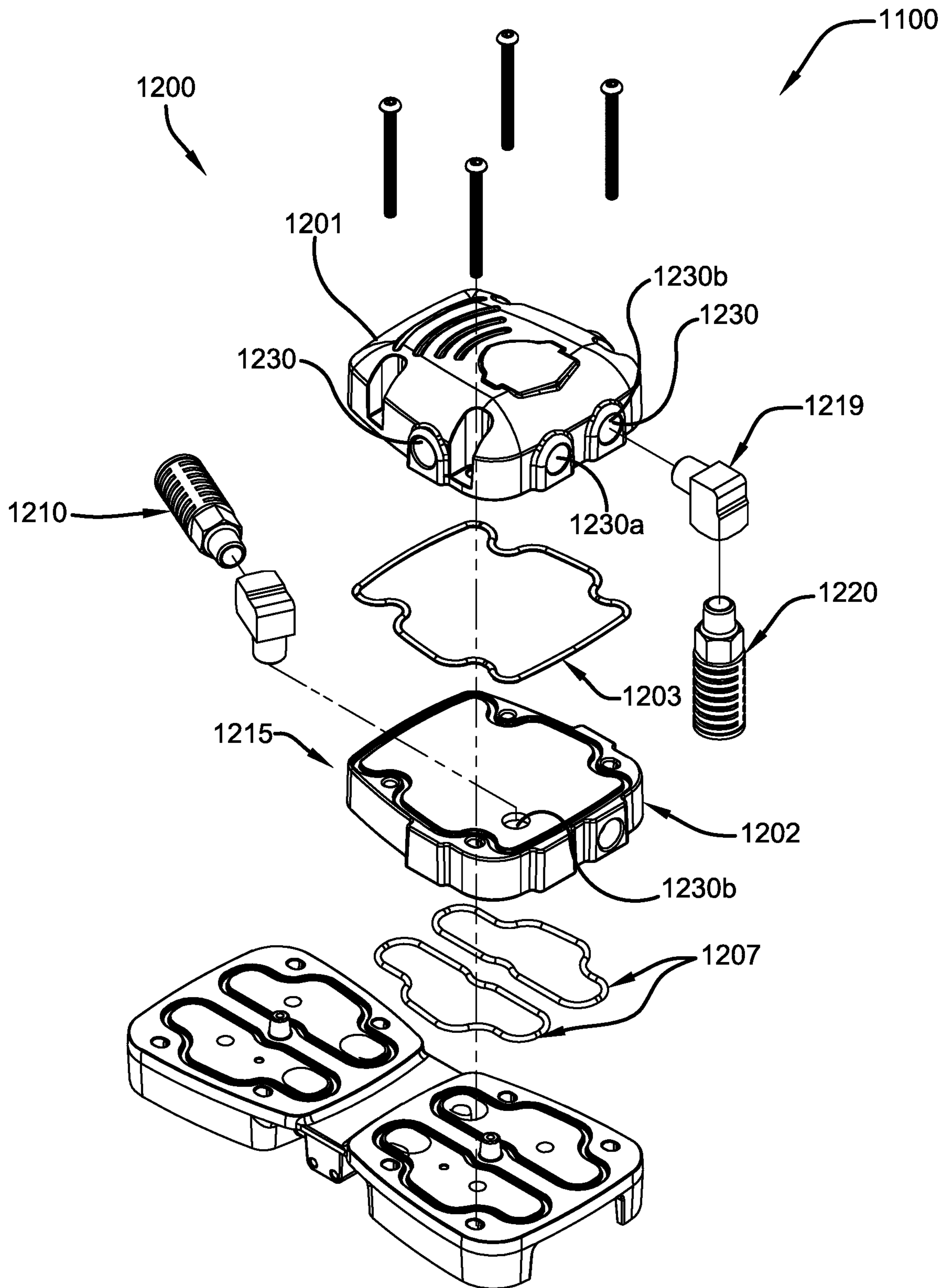


FIGURE 17

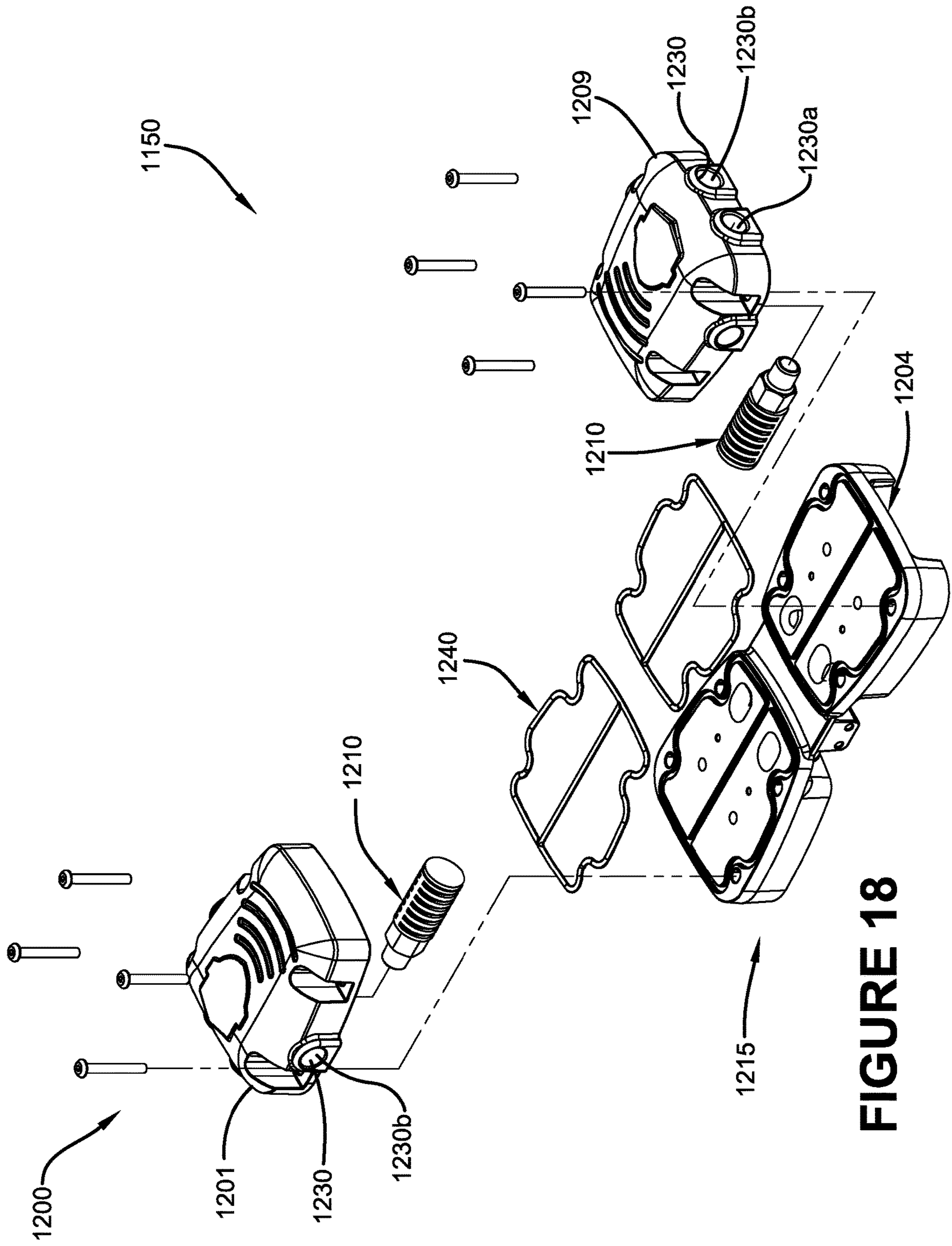
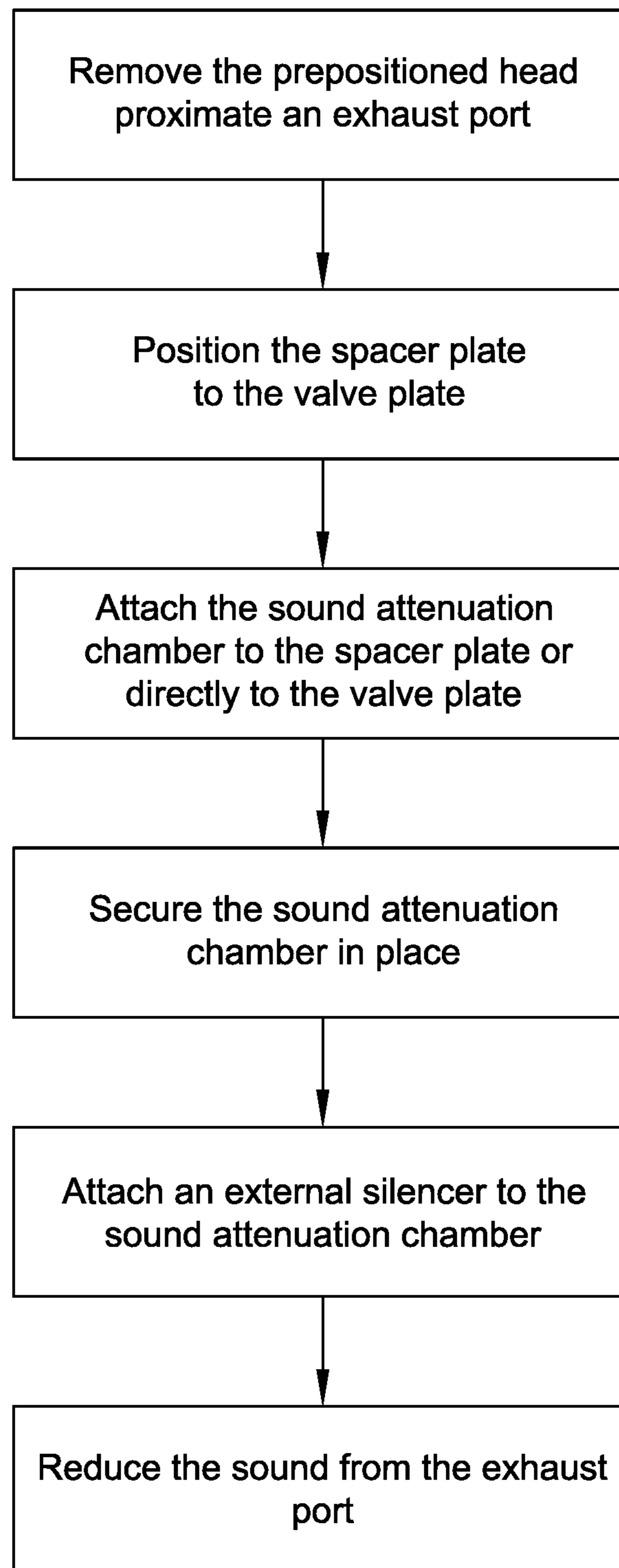
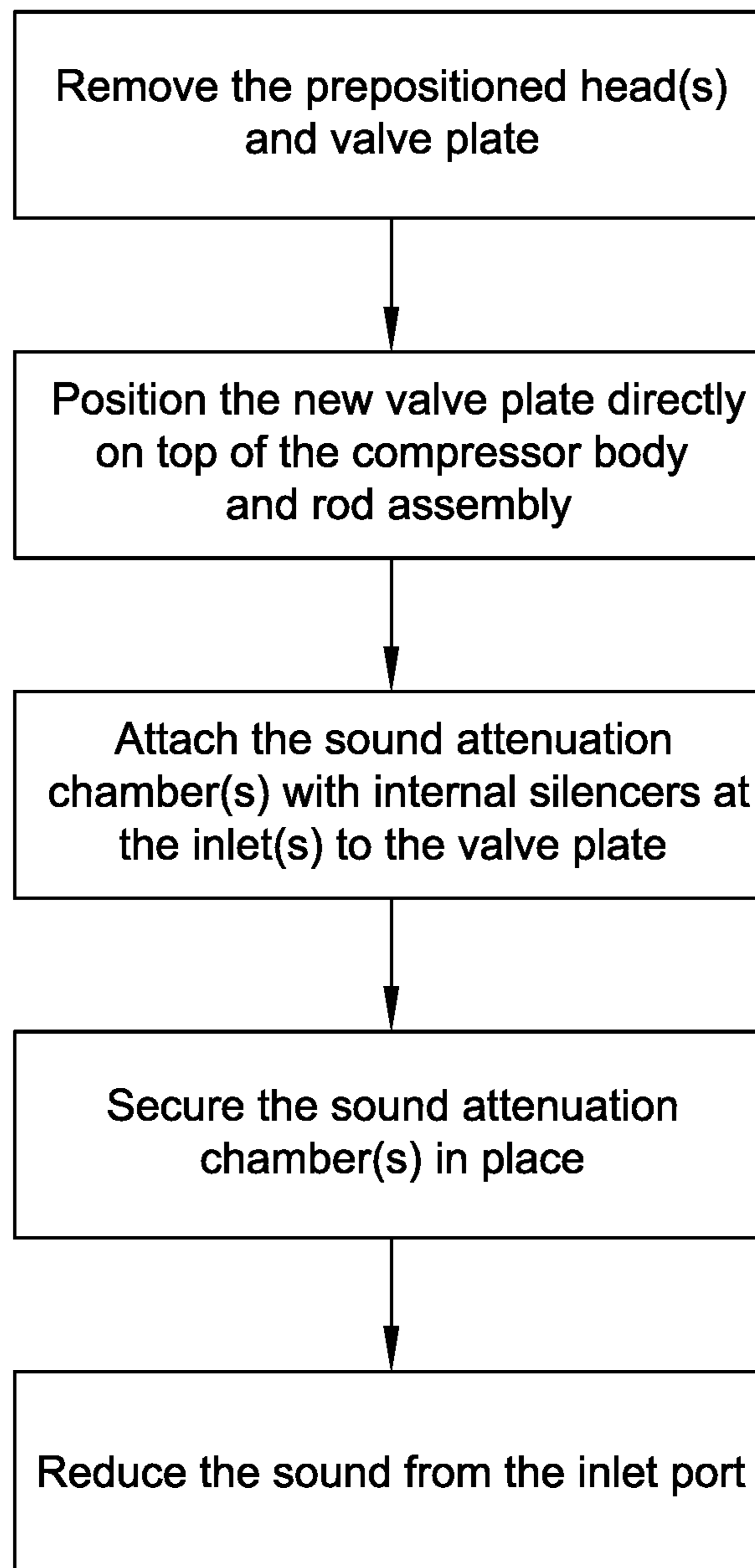


FIGURE 18

**FIGURE 19A**

**FIGURE 19B**

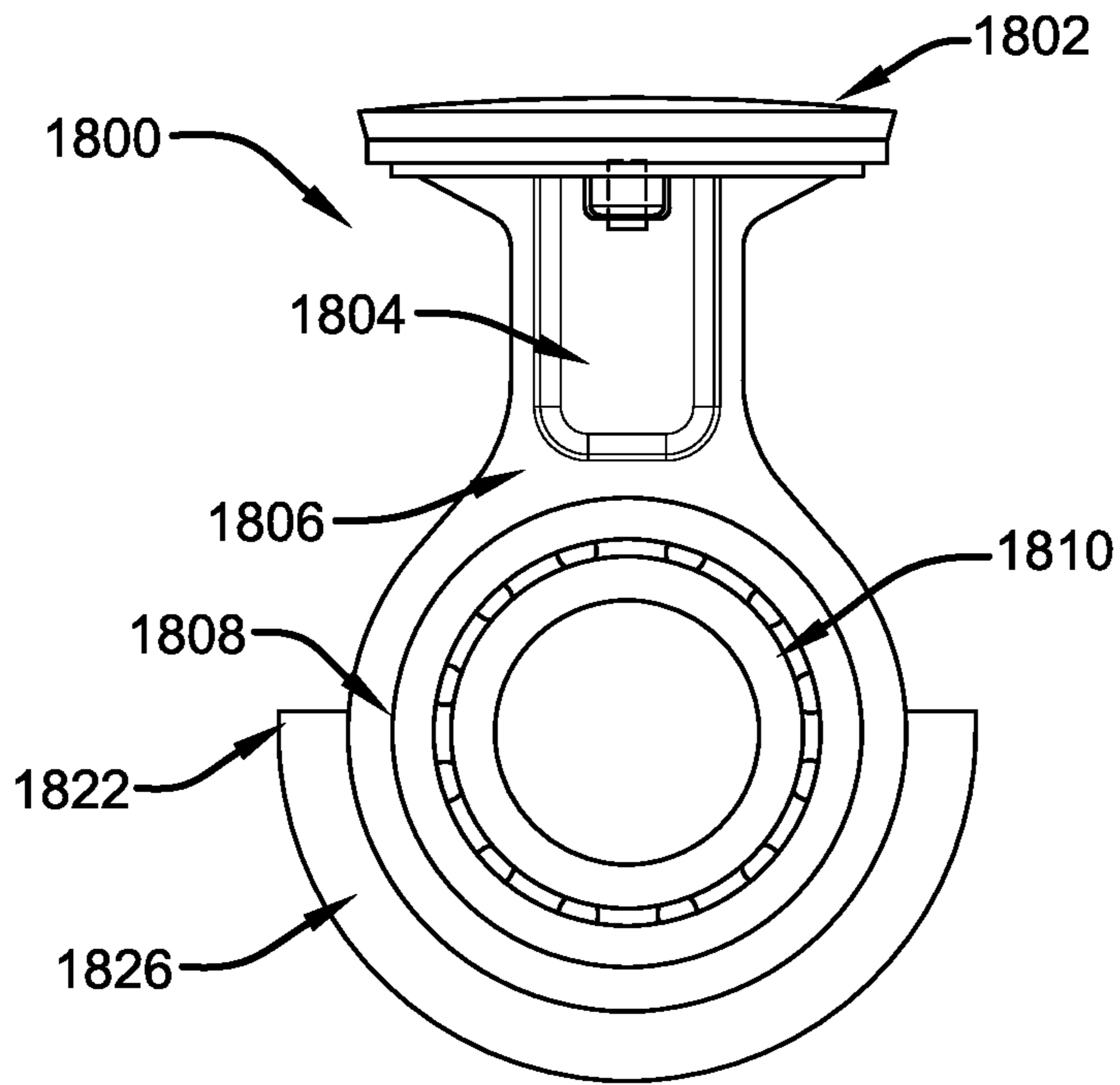


FIGURE 20

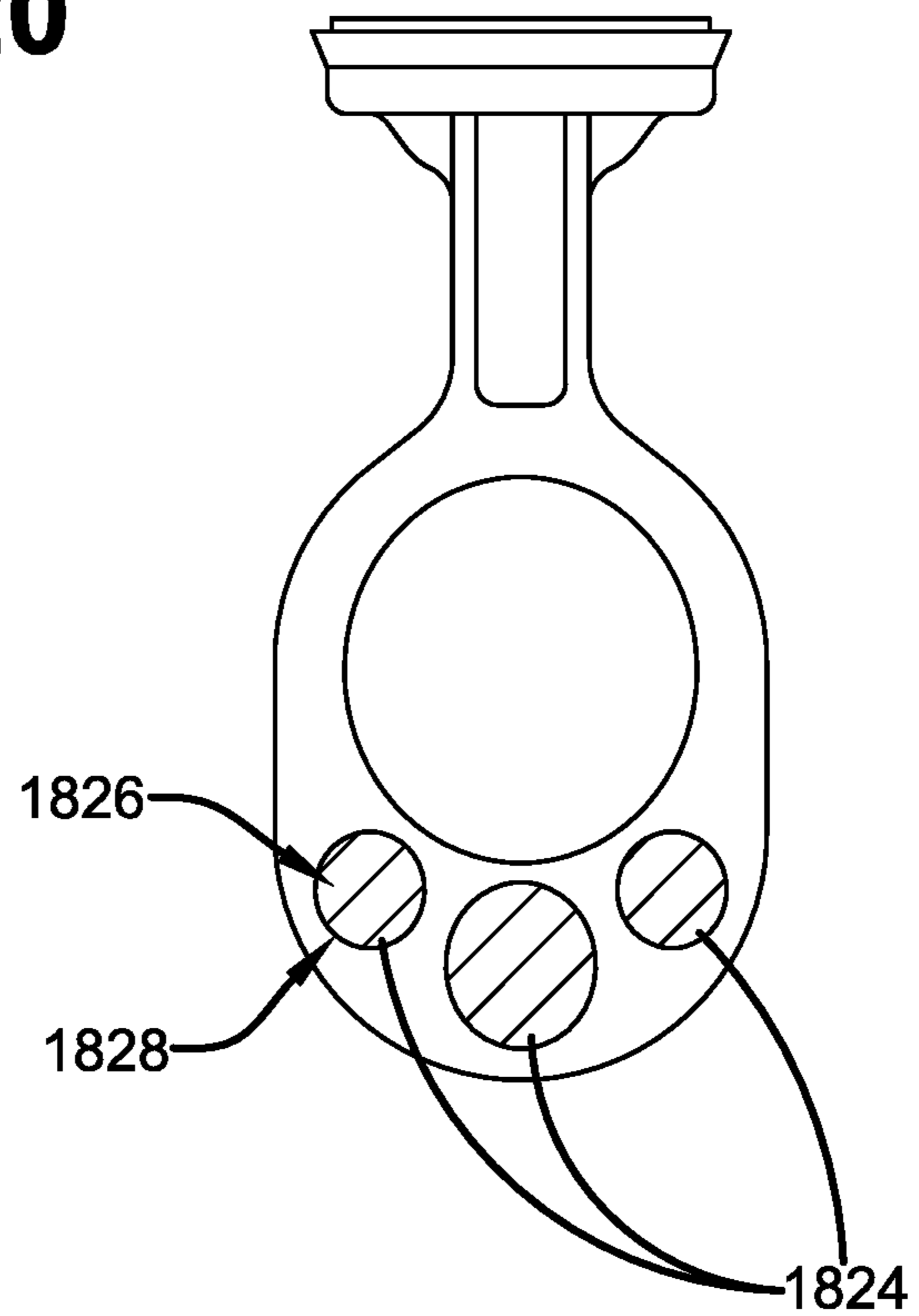


FIGURE 21

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SOUND REDUCTION DEVICE FOR ROCKING PISTON PUMPS AND COMPRESSORS

RELATED APPLICATION DATA

This application claims benefit of U.S. Provisional Application No. 62/840,107 filed Apr. 29, 2019, of which is incorporated herein by reference.

BACKGROUND

Sound attenuation and vibration reduction are desired for rocking piston vacuum pumps and compressors. In medical and dental applications, multiple pieces of equipment may be in the same proximate location. As multiple pieces of equipment are used, the decibel level may increase. After reaching a certain decibel level, sound in a room may become distracting. Discussion between a health care provider and patient difficult. Further, the noise may cause feelings of uneasiness if a patient is anxious. As such, reducing noise produced by rocking piston vacuum pumps and rocking pistons in medical and dental applications is desired.

SUMMARY

This Summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This Summary is not intended to identify key factors or essential features of the claimed subject matter, nor is it intended to be used to limit the scope of the claimed subject matter.

A rocking piston vacuum pump or compressor may have a sound attenuation chamber. The chamber may have a first silencer disposed therein. A second silencer may be disposed in series relative to the first silencer and may be disposed externally of the sound attenuation chamber.

To the accomplishment of the foregoing and related ends, the following description and annexed drawings set forth certain illustrative aspects and implementations. These are indicative of but a few of the various ways in which one or more aspects may be employed. Other aspects, advantages and novel features of the disclosure will become apparent from the following detailed description when considered in conjunction with the annexed drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

What is disclosed herein may take physical form in certain parts and arrangement of parts, and will be described in detail in this specification and illustrated in the accompanying drawings which form a part hereof and wherein:

FIG. 1 is a perspective view of a disclosed dual cylinder rocking piston compressor.

FIG. 2 is an exploded view of the compressor shown in FIG. 1.

FIG. 3A is top view of the valve plate assembly of the compressor shown in FIGS. 1 and 2.

FIG. 3B is bottom view of the valve plate assembly of the compressor shown in FIGS. 1 and 2.

FIG. 4 is an exploded view of the valve plate assembly shown in FIGS. 3A and 3B.

FIG. 5A is a sectional view taken substantially along lines 5A'-5A' of FIGS. 5B and 5A"-5A" of FIG. 5C.

FIG. 5B is a sectional view taken substantially along line 5B-5B of FIG. 5A.

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FIG. 5C is a sectional view taken substantially along line 5C-5C of FIG. 5A.

FIGS. 6A and 6B are perspective views of a disclosed single cylinder rocking piston compressor with multiple intake and exhaust ports for multiple configurations.

FIG. 7 is an exploded view of the compressor shown in FIG. 6.

FIG. 8A is top view of the valve plate assembly of the compressor shown in FIGS. 6-7.

FIG. 8B is bottom view of the valve plate assembly of the compressor shown in FIGS. 6-7.

FIG. 9 is an exploded view of the valve plate assembly shown in FIGS. 8A and 8B.

FIG. 10A is a sectional view taken substantially along lines 10A'-10A' of FIGS. 10B and 10A"-10A" of FIG. 10C.

FIG. 10B is a sectional view taken substantially along line 10B-10B of FIG. 10A.

FIG. 10C is a sectional view taken substantially along line 10C-10C of FIG. 10A.

FIG. 11 graphically illustrates a sound performance comparison of the disclosed dual cylinder rocking piston compressor vs. a prior art dual cylinder rocking piston compressor with the inlet and outlet plumbed away.

FIG. 12 is a perspective view of another implementation of a dual cylinder rocking piston vacuum pump.

FIG. 13 is a left side view of FIG. 12.

FIG. 14 is a perspective view of FIG. 12.

FIG. 15A is another perspective view of the rocking piston vacuum pump shown in FIG. 12.

FIG. 15B is a perspective view of the rocking piston vacuum pump shown in FIG. 12.

FIG. 16A is a perspective view of a sound attenuation chamber.

FIG. 16B is a side section view of the implementation shown in FIG. 12.

FIG. 16C is a front section view showing a first phase of the implementation shown in FIG. 12.

FIG. 16D is a front section view showing a second phase of the implementation shown in FIG. 12.

FIG. 16E is a front section view showing a third phase of the implementation shown in FIG. 12.

FIG. 17 is an exploded view of one example implementation of a sound attenuation chamber for a vacuum application.

FIG. 18 is an exploded view of one example implementation of a sound attenuation chamber for a pressure application.

FIG. 19A is a flow chart illustrating assembly of the sound attenuation chamber for an example vacuum application.

FIG. 19B is a flow chart illustrating assembly of the sound attenuation chamber for an example pressure application.

FIG. 20 is a front view of a rod assembly.

FIG. 21 is another front view of a rod assembly.

It should be understood that the drawings are not necessarily to scale and that the disclosed embodiments are sometimes illustrated diagrammatically and in partial views. In certain instances, details which are not necessary for an understanding of the disclosed methods and apparatuses or which render other details difficult to perceive may have been omitted. It should be understood, of course, that this disclosure is not limited to the particular embodiments illustrated herein.

DETAILED DESCRIPTION

Prior art FIGS. 1-11 represent a dual cylinder rocking piston-type compressor, as illustrated and described in

FIGS. 1-11 of U.S. Pat. No. 9,863,412. FIG. 1 illustrates a disclosed dual cylinder rocking piston-type compressor 20 with two heads 21, 22 that are mounted onto a valve plate body 23 that may include two distinct valve plates 24, 25 that may be coupled together by a crossover passageway housing 26. The two valve plates 24, 25 and crossover passageway housing 26 may be cast together as a single part or individual valve plates 24, 25 may be employed with conduits serving as the crossover passageways (not shown). For example, stiff or flexible tubes may be employed for the intake and exhaust crossover passageways as explained below. In the embodiment shown in FIG. 1, each head 21, 22 slopes towards its respective valve plate 24, 25 respectively as each head 21, 22 extends towards the crossover passageway housing 26. It has been found that this sloping feature of the heads 21, 22 provides for improved flow through the compressor 20 for quieter operation.

Referring to FIGS. 1 and 2, each valve plate 24, 25 may cover a cylinder 27, 28 respectively with a seal 31, 32 that may be sandwiched between each cylinder 27, 28 and a slot 33, 34 disposed on the underside 35, 36 of each valve plate 24, 25 as shown in FIG. 3B. As shown in FIG. 2, each head may include four ports 37, 38, 40a, 40b (head 21) and 39, 41, 40c, 40d (head 22). Only a single port is needed for an intake and only a single port is needed for an exhaust but more than one intake and more than one exhaust may be employed. Therefore, the plurality of ports 37, 38, 40a, 40b, 39, 41, 40c, 40d enables the user to employ the compressor 20 in a variety of configurations, as will be apparent to those skilled in the art. In the specific configuration illustrated in FIGS. 1-5C, any one or more of the ports 37, 40a, 40c, 41 may serve as intake ports (or intakes) and any one or more of the ports 38, 40b, 39, 40d may serve as exhaust ports (or exhausts). However, in the illustrated configuration, the ports 40a, 40c and 41 are plugged while the port 37 is unplugged and therefore the port 37 serves as a single intake for the compressor 20. Further, because the ports 38, 40b, 40c, 40d are plugged while the port 39 is unplugged, the port 39 serves as a single exhaust for the compressor in the configuration illustrated in FIGS. 1-5C. However, as shown in FIGS. 5B and 5C, the flow path may be easily reversed by removing the plugs 115, 116 from the ports 38, 41 and placing the plugs 115, 116 in the ports 37, 39 thereby enabling the port 41 to serve as the intake and the port 38 to serve as the exhaust (assuming that the side ports 40a, 40b, 40c, 40d are plugged). Additionally, the intake and exhaust sides may be reversed by switching the positions of the outlet valves 71, 72 and the inlet valves 82, 83 (see FIGS. 3A-3B). Thus, the compressor 20 is capable of multiple configurations.

As shown in FIGS. 2 and 5B, the valve plates 24, 25 may each include a slot 42, 44 that each may define intake chambers 87, 88 with the heads 21, 22 respectively. Each valve plate 24, 25 may also include slots 43, 45 that each may define exhaust chambers 89, 90 with the heads 21, 22 respectively as shown in FIG. 5C. The slots 42-45 may each accommodate a dedicated seal 46, 47, 48, 49 respectively (FIG. 2). The intake chambers 87, 88 and exhaust chambers 89, 90 along with the various sound attenuation chambers 91, 93, 94, 96, 97, 99, 101, 103 will be described in greater detail below.

Returning to FIG. 2, each cylinder 27, 28 may be disposed within a housing 51, 52 that may be disposed on either side of a motor 53 which rotates the drive shaft 54. The drive shaft 54 may pass through bearings 55, 56 before being coupled to the rocking pistons assemblies 57, 58 which are coupled to the drive shaft 54 by the engagement of a set

screw (not shown) extending from the rocking piston assemblies 57, 58 to flats or slots disposed on the motor shaft (only one of which is shown at 59 in FIG. 2). The reader will note from FIG. 2 that the rocking piston assemblies 57, 58 are 180. degree out of phase with each other, meaning that when one piston assembly 57 is performing an exhaust stroke, the other piston assembly 58 is performing an intake stroke and vice versa. Each rocking piston assembly 57, 58 may include piston heads 62, 63 that are slidably and sealably received within the cylinders 27, 28 respectively. Fans 65, 66 may be disposed between the pistons 57, 58 and the ventilated covers 66, 67 respectively for cooling purposes.

The top and bottom sides of the valve plate body 23 and the two valve plates 24, 25 are illustrated in FIGS. 3A-3B respectively. FIG. 3A shows the inlet 68 of the valve plate 24 which leads to the cylinder 27 while FIG. 3B shows the inlet valve 82 of the valve plate 24 disposed beneath the inlet 68 and within an upper portion of the cylinder 27. Similarly, FIG. 3A shows the inlet 69 of the valve plate 25 which leads to the cylinder 28 while FIG. 3B shows the inlet valve 83 disposed beneath the inlet 69 and within an upper portion of the cylinder 28. FIG. 3A also shows the exhaust valve 71 for the valve plate 24 and the cylinder 27 as well as the exhaust valve 72 for the valve plate 25 and the cylinder 28. FIG. 3A further shows an inlet 74 of the intake crossover passageway 78 (FIGS. 3B and 5B) as well as an outlet 75 of the intake crossover passageway 78. FIG. 3A also shows an inlet 76 of the exhaust crossover passageway 79 (FIGS. 3B and 5C) and an outlet 77 of the exhaust crossover passageway 79.

FIG. 3B illustrates the crossover passageway housing 26 for the intake and exhaust crossover passageways 78, 79. FIG. 3B also shows the inlet valve 82 disposed beneath the inlet 68 that leads to the cylinder 27 and the inlet valve 83 disposed beneath the inlet 69 that leads to the cylinder 28. An exploded view of the valve plate body 23, the exhaust valve 71, the inlet valve 82, and the inlet valve 83 is provided in FIG. 4. The plugs 85, 86 seal one end of each crossover passageway 78, 79 respectively as shown in FIGS. 5B-5C.

FIGS. 5A-5C illustrate the flow of air or gas through the chambers 87-90, 91, 93-94, 96, 97, 99, 101, 103 that are defined by the valve plate body 23 and the heads 21, 22. As noted above and shown in FIGS. 5B and 5C, the first and second valve plates 24, 25 and the heads 21, 22 may define first and second intake chambers 87, 88 respectively and first and second exhaust chambers 89, 90 respectively. The first and second intake chambers 87, 88 and the first and second exhaust chambers 89, 90 may be in communication with one or more sound attenuation chambers 91, 93 (intake chamber 87), 94, 96 (intake chamber 88), 97, 99 (exhaust chamber 89) and 101, 103 (exhaust chamber 90) via the baffles 105-112 as best seen in FIG. 5A.

As shown in FIG. 5B, air or gas enters the compressor 20 through the intake 37 before it passes through the sound attenuation chamber 91 and past the baffle 105 before it enters the intake chamber 87. The air or gas flows from the intake chamber 87, past the baffle 106 before entering the sound attenuation chamber 93 and the crossover passageway inlet 74, which directs the air or gas into the crossover passageway 78. The crossover passageway outlet 75 permits said air or gas to flow from the crossover passageway 78 through the sound attenuation chamber 94, past the baffle 107 and into the other intake chamber 88. As the air or gas flows through the intake side of the compressor 20, it is drawn downward through the inlets 68, 69 and into the cylinders 27, 28 where it is compressed.

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Conversely, as shown in FIG. 5C, air exits the compressor through the outlets 80, 81 before entering the exhaust chambers 89, 90. The crossover passageway inlet 76 receives air or gas from the exhaust chamber 89 after it passes the baffle 110 and after it passes through the sound attenuation chamber 99 before it is directed into the crossover passageway 79. The outlet 77 communicates the air or gas from the crossover passageway 79 into the sound attenuation chamber 101, past the baffle 111 and into the exhaust chamber 90. The air or gas then passes the baffle 112, proceeds through the sound attenuation chamber 103 and exits the compressor 20 through the exhaust port 39.

The additional port 41 may be sealed by the plug 115 and the additional port 38 may be sealed by the plug 116. However, as noted above, the direction of the flow may be reversed by using the port 41 as a single intake and the port 38 as a single exhaust. The side ports 40a, 40b, 40c, 40d may also be plugged, used as auxiliary intakes (ports 40a, 40b), auxiliary exhausts (ports 40c, 40d) or as single intakes or exhausts, depending on the desired configuration. As will be apparent to those skilled in the art, multiple configurations are available and an exhaustive list need not be mentioned here.

Still referring to FIGS. 5B-5C, the crossover passageways 78, 79 may be drilled and plugs 85, 86 may be used to seal the open ends of the crossover passageways caused by the drilling operation.

The flow through the compressor 20 for the illustrated configuration may be described in connection with FIGS. 5A-5C. The first intake chamber 87 may be a sound attenuation chamber itself and may be in communication with one or more sound attenuation chambers 91, 93. Gas/air flows through the intake port 37 and into the sound attenuation chamber 91 before passing the baffle 105 and entering the intake chamber 87 before passing the baffle 106 and entering the sound attenuation chamber 93. The air/gas then proceeds through the inlet 74 to the crossover passageway 78 before exiting through the outlet 75 and entering the sound attenuation chamber 94. The air or gas passes the baffle 107 before reaching the second intake chamber 88. The intake chamber 88 may also be in communication with the sound attenuation chamber 96 in addition to the sound attenuation chamber 94. In the first intake chamber 87, part of the air/gas proceeds through the inlet 68 and past the inlet valve 82 before it is compressed in the cylinder 27. In the second intake chamber 88, part of the air/gas also proceeds through the inlet 69 and past the inlet valve 83 before it is compressed in the cylinder 28.

After the air/gas is compressed in the cylinder 27, it passes upward through the outlet 80 and exhaust valve 71 and into the first exhaust chamber 89. The air then proceeds past the baffle 110, through the sound attenuation chamber 99 and through the inlet 76 to the crossover passageway 79 before exiting the crossover passageway through the outlet 77 and entering the sound attenuation chamber 101. The air/gas then passes the baffle 111 before entering the second exhaust chamber 90. Additional air/gas exits the cylinder 28 through the outlet 81 and exhaust valve 72 before entering the second exhaust chamber 90 and passing the baffle 112 as it enters the sound attenuation chamber 103 before it exits through the exhaust port 39.

As air/gas enters the intake 37 and expands in the sound attenuation chamber 91 before it is compressed as it passes the baffle 105. The air/gas expands again in the larger intake chamber 87 (see FIG. 5A). The increases and decreases in volume and/or pressure as the air passes through the intake port 37, through the sound attenuation chamber 91, past the

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baffle 105 and into the larger intake chamber 87 provides a sound attenuation effect. The air/gas is then compressed again as it proceeds past the baffle 106 before expanding as it proceeds through the sound attenuation chamber 93 and onto the inlet 74. In addition to the sound attenuation provide by the chamber 93, the cross-sectional diameter of the crossover passageway 78 is larger than the minimum diameter of the inlet 74, which causes the air/gas to expand again thereby providing the crossover passageway 78 with sound attenuation effects as well. As the air proceeds through the narrow portion of the outlet 75, it expands as it enters the sound attenuation chamber 94. As air passes the baffle 107, it is compressed again before entering the large intake chamber 88, which also provides a sound attenuation effect before the air/gas enters the cylinder 28 through the inlet 69. The valve plate 25 may include the baffle 108 to form a sound attenuation chamber 96 when the additional port 41 is used as the intake.

Similarly, referring to FIG. 5C, as air exits the cylinder 27, it passes through the exhaust valve 71 and expands in the exhaust chamber 89 before being compressed as it flows past the baffle 110 before expanding yet again as it enters the sound attenuation chamber 99. Then, the air/gas passes through the relatively narrow inlet 76 and into the crossover passageway 79 which has a larger diameter than the minimum diameter of the inlet 76 thereby providing a sound attenuation effect for the crossover passageway 79. The air/gas then contracts as it enters the outlet 77 before expanding as it enters the sound attenuation chamber 101 before being compressed as it passes the baffle 111. The air/gas then expands again as it enters the exhaust chamber 90. Air/gas exits the cylinder 28 through the exhaust valve 72 and into the exhaust chamber 90 before being compressed as it passes the baffle 112 and enters the final sound attenuation chamber 103 before exiting through the exhaust port 39.

Without being bound by theory, it is believed that the various disclosed sound attenuation chambers, intake chambers exhaust chambers and sloping heads, in combination with the baffles, provide expansion and compression of the air/gas as it proceeds through the sound attenuation chambers (and intake and exhaust chambers) and past the baffles before exiting through the exhaust port provides significant sound attenuation properties. These improved sound attenuation properties are presented in FIG. 11 where the line 300 represents the sound level of a conventional dual cylinder rocking piston type compressor and the line 301 represents the sound level of the disclosed dual cylinder rocking piston-type compressor 20.

A single cylinder rocking piston compressor 120 is illustrated in FIGS. 6A-10C. The compressor 120 may comprise a head 121 that covers a valve plate 124. The head 121 may include a plurality of ports 137, 138, 139, 141, 140a, 140b, 140c, 140d. Like the compressor 20 shown in FIGS. 1-5C, the head 121 slopes towards the valve plate 124 as the head 121 extends from one end of the valve plate 124 to the other end of the valve plate 124. The sloping configuration of the head 121 results in a reduction in the size of the chamber(s) defined by the head 121 and valve plate 124 for improved flow and quieter operation of the compressor 120.

In the configuration illustrated, all of the ports except the intake 137 and exhaust 139 are plugged, but the ports 140a, 140c and 141 could also serve as intakes and the ports 140b, 140d, and 138 could also serve as exhausts. Further, the intake and exhaust sides of the compressor 120 may be reversed in addition to the flow direction, as explained above in connection with the compressor 20 of FIGS. 1-5C. Thus,

the compressor **120** may assume multiple configurations like the compressor **20** discussed above and each configuration need not be listed here.

To reverse the flow direction of the compressor **120**, the plug **215** can be moved from the intake port **141** to seal the exhaust port **139** and the plug **216** can be removed from the exhaust port **138** to plug the intake port **137**. That arrangement (not shown in FIG. **6A**, **6B** or **7**) would establish the intake at the port **141** and the exhaust at the port **138**. As noted above, with the configuration of the inlet valve **171** (FIG. **8A**) and the exhaust valve **182** (FIG. **8B**), the port **140a** may also be used as an intake and/or the port **140c** may be used as an exhaust. Further, the ports **140b** may be used as an intake and/or the port **140d** may be used as an exhaust (and vice versa is the positions of the valves **171**, **182** are switched). Use of the ports **140b**, **140d** as the intake and exhaust may lower the profile of the compressor **120** when various plumbing accessories such as intake and exhaust filters and mufflers are attached. As an alternate construction (not shown) of valve plate body **23** used in the construction of compressor **20** (dual cylinder compressor), two valve plates **124** may have ports **140b** and **140d** modified to receive separate intake and exhaust chamber passageways of various construction methods, thereby providing communication between each valve plate. This alternate construction provides flexibility for future dual cylinder compressor configurations where a longer motor **53** with more power may be required to further expand the performance range of the compressor.

Turning to FIG. **7**, dedicated seals **146**, **147** may be accommodated in the channels **142**, **143** respectively for purposes of defining an intake chamber **187** and an exhaust chamber **189** and the related sound attenuation chambers **191**, **193**, **201**, **203** (see FIGS. **10A-10C**). Still referring to FIG. **7**, the valve plate **124** may be used to cover a cylinder **127**. An O-ring seal **131** may be sandwiched between the cylinder **127** and the underside of the valve plate **124**. The compressor motor **153** may rotate a drive shaft **154**, which may pass through a bearing **155** before it passes through the rocking piston assembly **158** and the fan **166**. The drive shaft **154** may also pass through an additional ring **156** and a bushing **217**. The motor may be partially accommodated in and supported by the main housing **152** and a ventilated end housing **167**. A ventilated cover **166** may be coupled to the main housing **152** for purposes of protecting the fan **166**. The bearing **166** may be covered by an end cap **218**. Various fasteners are shown at **220**, **221** for purposes of holding the compressor **120** together.

Turning to FIGS. **8A-8B**, top and bottoms views of the valve plate **124** are shown. The valve plate **124** may include slots or grooves **142**, **143** for purposes of accommodating the seals **146**, **147** respectively (see FIG. **7**). An exhaust valve **171** may cover an outlet **180**. An intake valve **82** covers the underside of the inlet **168** shown in FIG. **8A** while the exhaust valve **171** covers the upper side of the outlet **180**. A slot or groove **133** accommodates the O-ring **131** shown in FIG. **7**.

FIG. **9** is an exploded view of the valve plate **124**, exhaust valve **171**, and intake valve **182**. FIGS. **10A-10C** illustrates the air/gas flow through the compressor **120**. Air enters through the intake port **137** and passes into the intake chamber **187**. The intake chamber **187** may be in communication with a plurality of sound attenuation chambers **191**, **193**. The sound attenuation chambers **191**, **193** may be defined by the baffles **205**, **206** as well as the head **121** and valve plate **124**. Further, as discussed above in connection with the compressor **20** illustrated in FIGS. **1-5C**, successive

expansions and contractions of the volume or cross-sectional area through which the air/gas passes provides sound attenuation. Therefore, as air/gas enters the intake port **137**, it expands into the sound attenuation chamber **191** before it is compressed again as it passes the baffle **205**. The air/gas is then expanded again as it enters the large intake chamber **187**. The gas/air exits the intake chamber **187** through the inlet **168** as it passes through the intake valve **182** (FIG. **10B**). The sound attenuation chamber **193** and baffle **206** assists with sound attenuation, but also acts as a sound attenuation chamber when the additional port **141** is used as the intake.

Turning to FIG. **10C**, air/gas exits the cylinder **127** through the outlet **180** and past the exhaust valve **171** before it enters the exhaust chamber **189**. Similar to the intake chamber **187**, the exhaust chamber **189** may be in communication with a plurality of sound attenuation chambers **201**, **203** that may be defined by the baffles **211**, **212**, the head **121** and valve plate **124**. As air/gas passes upward through the outlet **180** and past the exhaust valve **171**, it expands into the large exhaust chamber **189**. As the air/gas moves toward the exhaust port **139**, it is compressed as it passes the baffle **211** before it is expanded again in the sound attenuation chamber **203** prior to exiting the compressor **120** through the exhaust **139**. The baffle **212** and the sound attenuation chamber **201** provide sound attenuation benefits, but are used primarily when the additional port **141** serves as the exhaust.

As suggested above in regard to the compressor **20** of FIGS. **1-5C**, without being bound by theory, it is believed that the successive expansions and contractions of the air or gas passing through the compressor **120** provides significant sound attenuation as graphically illustrated in FIG. **11** even though the curve **301** was generated with a dual rocking piston compressor **20** as opposed to a single cylinder rocking piston compressor **120**.

With reference to FIGS. **12-19** another implementation of a sound attenuation assembly **1200** is described. FIGS. **12-19** show example implementations of the sound attenuation assembly utilized for vacuum applications and pressure applications that may apply to pumps and/or compressors. Pressure applications and vacuum applications may utilize a single head or a dual head. In one example implementation, pressure applications may utilize a silencer at an inlet of the sound attenuation chamber **1200**. In another example implementation, vacuum applications may utilize a silencer at an exhaust or outlet of the sound attenuation chamber.

The sound attenuation assembly **1200** may be utilized with a compressor or a vacuum pump. In another implementation, the sound attenuation assembly **1200** may be utilized with a rocking piston compressor or a rocking piston vacuum pump. In one implementation, the sound attenuation assembly may be selectively removable from the head of the vacuum pump or compressor. The sound attenuation assembly may be sold as a kit to retrofit onto existing compressors and pumps. In one example implementation, by disposing two mufflers, as described below in series, decibel levels may be reduced. In one implementation sound levels may be reduced from about 69 dB(A) (20 Sones) to about 54 dB(A) (9.6 Sones) consistently, when intake air is plumbed away from a sound room (not shown) and the outlet exhausts to the atmosphere within the sound room.

As shown in FIG. **12-19**, the sound attenuation assembly **1200** may comprise an exhaust sound attenuation chamber **1201**. In one implementation, the sound attenuation chamber **1201** may replace one of the heads of the compressor or pump. The sound attenuation chamber **1201** may comprise

one or more ports **1230**. Ports **1230** may be an inlet port **1230a** or an outlet port **1230b**. The sound attenuation chamber **1201** may be operably connected to a base **1204**. The sound attenuation chamber **1200** may comprise a first silencer **1210** or muffler. The first silencer **1210** or muffler may be internal. In one implementation, the first silencer **1210** may be a SMC ANA1-02. The internal silencer **1210** may be partially or completely engulfed or surrounded with sound dampening foam **1212**.

The sound dampening foam **1212** may be any foam chosen with sound engineering judgment. By way of non-limiting example, sound dampening foam **1212** may be open-cell foam. The sound dampening foam **1212** may be an insulation material that absorbs multi-frequency noise, minimizes reverberation, improves acoustics, and/or may keep sound from escaping the enclosed area of the sound attenuation chamber **1201**. The sound dampening foam **1212** disposed inside the sound attenuation chamber **1201** may be disposed to adequately surround the internal silencer to minimize sound. For example, small pieces of sound dampening foam **1212** may be disposed in the sound attenuation chamber **1201**. In another nonlimiting example, larger pieces of sound dampening foam **1212** may be disposed in the sound attenuation chamber **1200**. The pieces of sound dampening foam **1212** may be loosely packed or densely packed around the internal silencer. The sound dampening foam **1212** may partially fill or completely fill the sound attenuation chamber **1201**. In another alternative embodiment, the sound dampening foam **1212** is disposed inside the sound attenuation chamber **1200** such that an operator may easily access the internal silencer for repair or replacement. In one implementation, the sound dampening foam **1212** or open-cell foam acts as a sound absorber, which may further reduce the amplitude of air exhaust noise.

With reference to FIGS. **12-18**, one example implementation of the sound attenuation assembly **1200** is shown as used with a rocking piston vacuum pump **1100**. The sound attenuation chamber **1201** may be operatively connected to the base **1215**. In one implementation, the sound attenuation chamber **1201** may be operably connected to the rocking piston pump **1100** by way of the base **1215**, which may be a spacer plate **1202**. An o-ring **1203** or other seal may be interposed between the sound attenuation chamber **1201** and the spacer plate **1202**. The spacer plate **1202** may be operably connected to a valve plate **1204**. In one example implementation, the spacer plate **1202** may be operably connected to the valve plate **1204**. The valve plate **1204** may be configured to be proximate a cylinder (previously described). The valve plate **1204** may comprise an inlet and an outlet that are in communication with the cylinder. The spacer plate **1202** may comprise an inlet chamber. An o-ring **1207** or other seal may be interposed between the spacer plate **102** and the valve plate **1204**. The internal silencer **1210** may be mated directly onto or operably connected to the spacer plate **1202**. A second silencer **1220** may be operably connected to the sound attenuation chamber **1201**. The second silencer **1220** may be at least partially external to the sound attenuation chamber **1201** in a vacuum application. The second silencer **1220** may be operably connected to the sound attenuation chamber **1200** through one of the ports **1230** of the sound attenuation chamber **1201**. In another implementation of a vacuum application, the second silencer **1220** may be operably coupled to the exhaust port **1230b** of the sound attenuation chamber by means of an elbow **1219**. The second silencer **1220** may also be a SMC ANA1-02 silencer. The combination of placing the two silencers **1210**, **1220** in series may produce sound dampen-

ing of exhaust air from the pump or compressor with minimal air restriction. The sound dampening foam **1212** may add additional sound reduction. Any open ports **1230** may be closed with a port plug **1232**.

With references to FIGS. **16A-E**, operation of the dual-head rocking piston remains the same as previously described. FIGS. **16A-E** describes one example implementation of air flow for a vacuum application. The sound attenuation chamber **1200** may reduce air exhaust noise. Turning to FIGS. **16A-16E**, an example of phases of air from intake to exhaust are shown. FIG. **16B** illustrates intake of atmospheric air filling an air inlet chamber of the spacer plate. Intake of atmospheric air may create suction during the downstroke of a rod. The air passes through the rocking piston compressor as previously described.

After passing through the compressor, the intake atmospheric air passes into an exhaust chamber disposed in the spacer plate. This may occur with a valve limiter during the upstroke of the rod. As such, the exhaust air is routed through the valve limited and then into the exhaust chamber of the spacer plate of the sound attenuation chamber **1200**.

In another implementation, the sound attenuation chamber **1200** may process exhaust air in a plurality of phases to reduce sound. One example of such implementation may process the exhaust air in three phases. As shown in FIG. **16C**, exhaust air may pass into the exhaust chamber or exhaust cavity of the spacer plate. The exhaust air may enter the first silencer **1210** at a first velocity **V1**. The first velocity **V1** may be at a high velocity. Once the exhaust air is in the first silencer **1210**, the exhaust air may be redirected into smaller streams of air that reflect off opposing walls within the silencer. It is believed that as air particles collide with each other, molecular velocity is reduced and the exhaust air is dispersed through small openings throughout the silencer at a second reduced velocity **V2**. Due to the reduced velocity, noise is reduced.

A second phase is shown in FIG. **16D**. When the exhaust air exits the first silencer **1210**, the exhaust air enters the sound attenuation chamber **1200**. Sound dampening foam **1212** may be disposed inside the sound attenuation chamber **1200** as previously described. In one implementation, the sound dampening foam **1212** or open-cell foam acts as a sound absorber, which may further reduce the amplitude of air exhaust noise. By adding this volume of the sound attenuation chamber **1200** in conjunction with the sound dampening foam **1212**, reflections of the noise, i.e. sound waves, weakens and causes a dulled sound effect.

A third phase is shown in FIG. **16E**. After exhaust air expands and fills the sound absorbing foam filled sound attenuation chamber **1200**, exhaust air is then directed to an outlet hole of the sound attenuation chamber **1200**. The second silencer **1220** is operably connected to the side wall of the sound attenuation chamber **1200** by way of the outlet hole. The second silencer **1220** may be positioned in series relative to the first silencer **1210**. The exhaust air may enter the second silencer **1220** at a third velocity **V3**. The third velocity **V3** is less than velocity **V2**, which is less than velocity **V1**. Once the exhaust air is in the second silencer **1220**, the exhaust air may be redirected into smaller streams of air that reflect off opposing walls within the second silencer **1220**. As air particles collide with each other, molecular velocity is reduced and the exhaust air is dispersed through small openings throughout the silencer at a fourth reduced velocity **V4**, which is less than velocity **V3**. Exhaust air may exit the second silencer **1220** and be dispersed into the atmosphere.

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In another implementation, the sound attenuation assembly **1200** may be operably connected to a pressure application. In one implementation, the pressure application may be a compressor **1150** or a rocking piston compressor **1150** as shown in FIG. **18**. In one implementation, the compressor or pump in a pressure application **1150** may have dual or single heads. The sound attenuation assembly **1200** may have the first sound attenuation chamber **1201**. It may also comprise a second sound attenuation chamber **1209**. Each sound attenuation chamber **1201**, **1209** may be operably coupled to the base **1215**. In the pressure application, the base **1215** may be the valve plate **1204**. An o-ring **1240**, o-ring gasket or other seal may be utilized to sealingly couple the sound attenuation chamber **1201** to the valve plate **1204**. The valve plate **1204** may be proximate a cylinder. The valve plate **1204** may comprise an inlet and an outlet that are in communication with the cylinder. At least one sound attenuation chamber **1201** may have the first silencer **1210**. The second sound attenuation chamber **1209** may also have a second silencer **1220**. Optionally, additional silencers may be operably coupled to the sound attenuation ports **1230** to further reduce sound. In one example implementation of a pressure application **1150**, the first silencer **1210** may be operably connected to the inlet port **1230a** of the sound attenuation chamber **1201**.

It should be understood that any number of silencers may be used in connection with the sound attenuation chamber to achieve noise reduction. For larger rocking piston compressors or pumps, two or more internal silencers may be used internally or externally given the application (vacuum or pressure).

With reference to FIGS. **19A** and **19B**, the sound attenuation assembly **1200** may be installed onto a vacuum application **1100**, such as but not limited to a rocking piston vacuum pump **1100** or a pressure application **1150**, such as but not limited to the rocking piston compressor **1150** with the following steps. The positioned head may be removed. For vacuum model applications, the spacer plate may be positioned proximate the valve plate, for example in an application with the vacuum pump. For pressure model applications, the spacer plate may not be utilized. The sound attenuation chamber may be positioned either to the spacer plate (for vacuum model applications) or the valve plate (for pressure model applications). The sound attenuation may comprise the first silencer disposed therein. For vacuum applications, the first silencer may be operably connected to the exhaust or outlet port **1230b** of the sound attenuation chamber. For pressure applications, the first silencer may be operably connected to the inlet port **1230a** of the sound attenuation chamber. The second silencer may be operably connected to one of the exhaust ports of the sound attenuation chamber in a vacuum application. The sound is then reduced during operation of the rocking piston vacuum pump or the rocking piston compressor.

With reference to FIGS. **20** and **21**, another implementation of a rocking piston compressor is illustrated to reduce vibration. The compressor may have a rod assembly **1800** which may be operably connected to the draft shaft **54**, which has been previously described. The rod assembly **1800** may comprise a piston head **1802**, a rod **1804**, and a rod assembly body **1806**. The rod assembly body **1806** may have a bore **1808** for positioning a bearing **1810** therein. The rod assembly **1800** has a center of mass CM. A counterbalance weight **1820** may be disposed on the rod assembly **1800** to move the center of mass from the center of the rod assembly **1800** to a center of the bearing **1810** or bearing bore **1808**. Vibration transmission is minimized from the rod

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and shaft. It is believed that the exerting forces will be reduced from about 11 Newtons to about 0 Newtons. In one nonlimiting implementation, tungsten may be used to provide the correct amount of mass due to possible space constraints within the compressor.

In one nonlimiting example, the counter balance weight **1820** may be positioned on a lower portion of the rod assembly body **1806**. In one implementation, the counterbalance weight **1820** may be positioned on an exterior surface **1807** of the rod assembly body **1806**. In another implementation, the counterbalance weight **1820** may have an edge **1822**, and the edge **1822** may be disposed concentric with the bearing bore **1808** or below the center of the bearing **1810**. In another implementation, holes **1824** may be bored in the bottom portion of the rod assembly body **1806**, where the holes **1824** may be filled with dense metal **1826**, such as, but not limited to tungsten **1828**. By moving the center of mass to be coincident with the center of the bearing or the bearing bore, vibration may be minimized.

Within applications, such as but not limited to medical and dental system applications, that require little to no vibration, particularly when mounted to a cabinet system. Reducing compressor vibration may also contribute to a longer life cycle of the compressor components and the compressor itself. By positioning the rod assembly's center of mass to be substantially concentric with the center of the bearing bore, dynamic balance becomes more stable when the eccentric is included, resulting in minimizing dynamic forces. In minimizing vibration of the compressor through rod assembly alterations, the compressor will experience less wear and tear.

Finally, the disclose compressors are capable of assuming multiple configurations, including low profile configurations and configurations which may permit the use of a larger motor. The flow direction of the compressors may be easily reversed.

The word "exemplary" is used herein to mean serving as an example, instance or illustration. Any aspect or design described herein as "exemplary" is not necessarily to be construed as advantageous over other aspects or designs. Rather, use of the word exemplary is intended to present concepts in a concrete fashion. As used in this application, the term "or" is intended to mean an inclusive "or" rather than an exclusive "or." That is, unless specified otherwise, or clear from context, "X employs A or B" is intended to mean any of the natural inclusive permutations. That is, if X employs A; X employs B; or X employs both A and B, then "X employs A or B" is satisfied under any of the foregoing instances. Further, at least one of A and B and/or the like generally means A or B or both A and B. In addition, the articles "a" and "an" as used in this application and the appended claims may generally be construed to mean "one or more" unless specified otherwise or clear from context to be directed to a singular form.

Although the subject matter has been described in language specific to structural features and/or methodological acts, it is to be understood that the subject matter defined in the appended claims is not necessarily limited to the specific features or acts described above. Rather, the specific features and acts described above are disclosed as example forms of implementing the claims. Of course, those skilled in the art will recognize many modifications may be made to this configuration without departing from the scope or spirit of the claimed subject matter.

Also, although the disclosure has been shown and described with respect to one or more implementations, equivalent alterations and modifications will occur to others

skilled in the art based upon a reading and understanding of this specification and the annexed drawings. The disclosure includes all such modifications and alterations and is limited only by the scope of the following claims. In particular regard to the various functions performed by the above described components (e.g., elements, resources, etc.), the terms used to describe such components are intended to correspond, unless otherwise indicated, to any component which performs the specified function of the described component (e.g., that is functionally equivalent), even though not structurally equivalent to the disclosed structure which performs the function in the herein illustrated exemplary implementations of the disclosure.

In addition, while a particular feature of the disclosure may have been disclosed with respect to only one of several implementations, such feature may be combined with one or more other features of the other implementations as may be desired and advantageous for any given or particular application. Furthermore, to the extent that the terms “includes,” “having,” “has,” “with,” or variants thereof are used in either the detailed description or the claims, such terms are

The implementations have been described, hereinabove. It will be apparent to those skilled in the art that the above methods and apparatuses may incorporate changes and modifications without departing from the general scope of this invention. It is intended to include all such modifications and alterations in so far as they come within the scope of the appended claims or the equivalents thereof.

What is claimed is:

1. A sound attenuation assembly for a pressure application for a rocking piston compressor or rocking piston pump, the rocking piston compressor or rocking piston pump, comprising:

a first rocking piston assembly operably connected to a first cylinder;

a second rocking piston assembly operably connected to a second cylinder;

a valve plate body comprising a first valve plate coupled to a second valve plate by a crossover passageway, wherein the first valve plate proximate the first cylinder, and wherein the second valve plate proximate the second cylinder;

a first head arranged over the first valve plate and comprising a first intake port and a first exhaust port;

a second head arranged over the second valve plate comprising a second intake port and a second exhaust port;

the sound attenuation chamber assembly, comprising:

a first sound attenuation chamber operably connected to and arranged proximate the first valve plate, the first sound attenuation chamber disposed over the first head;

a second sound attenuation chamber operably connected to and arranged proximate the second valve plate, the second sound attenuation chamber disposed over the second head; and,

a first silencer operably disposed in the first sound attenuation chamber and a second silencer disposed in the second sound attenuation chamber,

wherein the first and second sound attenuation chambers and the first and second silencers are configured to reduce sound for the rocking piston compressor or the rocking piston pump, wherein the first silencer and the second silencer receive air in parallel at the respective intake ports in the pressure application.

2. The sound attenuation assembly of claim **1**, further comprising at least one additional silencer disposed in the first attenuation chamber.

3. The sound attenuation assembly of claim **1**, wherein the first sound attenuation chamber is selectably removable from the first valve plate and the second sound attenuation chamber is selectably removable from the second valve plate.

4. The sound attenuation-assembly of claim **1**, further comprising foam, the foam at least partially engulfing the first silencer.

5. The sound attenuation assembly of claim **1**, further comprising at least one additional silencer disposed in the second sound attenuation chamber.

6. The sound attenuation assembly of claim **1**, wherein the first sound attenuation chamber is sealingly coupled to the first valve plate with an o-ring or gasket and the second sound attenuation chamber is sealingly coupled to the second valve plate with an o-ring or gasket.

7. A sound attenuation assembly for a rocking piston pump or a rocking piston compressor, comprising:

a valve plate proximate a cylinder, the valve plate comprising an inlet and an outlet that are in communication with the cylinder;

a sound attenuation chamber operably connected to the valve plate, the sound attenuation chamber having an inlet port and an outlet port;

a first silencer operably connected to the sound attenuation chamber, wherein the first silencer is operably connected to the inlet port for a pressure application or the first silencer is operably connected to the outlet port for a vacuum application;

a spacer plate interposed between the sound attenuation chamber and the valve plate, wherein the spacer plate defines a chamber for air and is arranged between the sound attenuation chamber and the valve plate; and an additional valve plate proximate an additional cylinder and coupled to the valve plate by a crossover passageway;

the rocking piston compressor or the rocking piston pump, comprising:

a first rocking piston operably connected to the cylinder; and

a second rocking piston operably connected to the additional cylinder; and

a head arranged over the additional valve plate and comprising a first intake port and a first exhaust port.

8. The sound attenuation assembly of claim **7**, further comprising a second silencer mated onto and disposed external to the spacer plate, wherein the second silencer is in series with the first silencer.

9. The sound attenuation assembly of claim **7**, further comprising sound dampening foam at least partially engulfing the first silencer and at least partially filling the sound attenuation chamber.

10. The sound attenuation assembly of claim **7**, wherein the spacer plate has outer sidewalls arranged directly over outer sidewalls of the valve plate, wherein the outer sidewalls of the spacer plate are arranged directly below outer sidewalls of the sound attenuation chamber, and wherein the spacer plate is sealed to the valve plate and is sealed to the sound attenuation chamber.

11. A method for reducing sound in a rocking piston vacuum pump or rocking piston compressor, comprising the steps of:

removing a prepositioned head from a valve plate;

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positioning a spacer plate over the valve plate after removing the prepositioned head;

positioning a sound attenuation chamber to the spacer plate after positioning the spacer plate, the sound attenuation chamber comprising an inlet port and an outlet port;

operably connecting a first silencer to the inlet port for a pressure application or operably the first silencer to the outlet port for a vacuum application; and

reducing sound during operation of the rocking piston vacuum pump or the rocking piston compressor.

12. The method of claim **11**, further comprising the step of operably connecting a second silencer externally to the sound attenuation chamber and in series with the first silencer.

13. The method of claim **11**, the valve plate configured to be proximate a cylinder, the valve plate including an inlet and an outlet that are in communication with the cylinder.

14. The method of claim **11**, wherein the first silencer is mated directly onto the spacer plate.

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15. A sound attenuation assembly for a rocking piston pump or a rocking piston compressor, comprising: a valve plate proximate a cylinder, the valve plate comprising an inlet and an outlet that are in communication with the cylinder; a sound attenuation chamber operably connected to the valve plate, the sound attenuation chamber having an inlet port and an outlet port; a first silencer operably connected to the sound attenuation chamber, wherein the first silencer is operably connected to the inlet port for a pressure application or the first silencer is operably connected to the outlet port for a vacuum application; a spacer plate interposed between the sound attenuation chamber and the valve plate, wherein the spacer plate defines a chamber for air and is arranged between the sound attenuation chamber and the valve plate; an additional valve plate proximate an additional cylinder and coupled to the valve plate by a crossover passageway, and a head arranged over the additional valve plate and comprising a first intake port and a first exhaust port, wherein the sound attenuation chamber is arranged above a topmost surface of the head.

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